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I. INTRODUCTION

The mosquito fauna of Minnesota, although not restricted to this region, has never been the object of a detailed study in the North Central States. Any rational control measure designed to alleviate the scourge of these pests must be based on a thorough knowledge of the life histories, habits, and bionomics of the species involved. The object of this study has been to determine the relative importance of the species occurring in the state and to investigate their biologies under the prevailing environmental conditions. An effort has also been made to point out available sources of information and to present keys for the determination of species found, or likely to be found, in this region as aids to others who may continue the study.

That mosquitoes were a veritable plague in Minnesota in the pioneer period and a scourge to the early settlers is evident from the reports of their abundance at that time. Prof. C. V. Riley (1882), in speaking of the annoyance from these insects, said: "Those who have traveled in summer on the lower Mississippi or in the Northwest have experienced the torment which these frail flies can inflict; at times they drive everyone from the boat, and trains can sometimes only be run with comfort on the Northern Pacific by keeping a smudge in the baggage car and the doors of all the coaches open to the fumes. The bravest man on the fleetest horse dares not cross some of the more rank and dark prairies of Northern Minnesota in June."

The importance of mosquitoes in relation to the early development of the state was recognized by Prof. Otto Lugger, the first state entomologist of Minnesota. In his second annual report (1896), he mentions some of the common species and discusses the problem of mosquito control. Of particular interest is this quotation from that early report: "The mosquito is still a great pest in some places in Minnesota, sometimes even killing animals that cannot escape, but the prairies are rapidly settled in spite of them, and, as the land is gradually better drained, mosquitoes have become fewer and fewer."

The prairie region of the state was not alone in producing hoards of these pests. Accounts of their abundance in the northern forest are not so graphic. Yet, if we may judge from their present numbers in that part of the state which has undergone less change since the pioneer

[1] It is a pleasure for the writer to acknowledge the able assistance extended by Dr. William A. Riley, Dr. Clarence E. Mickel, and other members of the Division of Entomology of the University of Minnesota during the pursuit of this study and the presentation of the data.

period, it becomes evident that there also they were a scourge to man and the larger game animals.

Washburn (1903) makes reference to attempts on the part of the state entomologist to abate the mosquito nuisance in a suburb of St. Paul. After treating many of the local breeding grounds with oil, he found that the area infested was too large for the available funds and the project was abandoned. Washburn (1912) again discusses the mosquito problem of the state and adds that 17 species have been found in Minnesota.

C. W. Howard, after wide experience gained in mosquito work in Africa, became affiliated with the Division of Entomology in 1912. During the next four years he made observations on the Minnesota species. In the summer of 1916, he was instrumental in promoting a mosquito-abatement project in a localized area in Minneapolis. This work was sponsored by the Minneapolis Real Estate Board and, unfortunately, was abandoned after one season's activity.

Howard (1916), in the annual report of the state entomologist, lists 19 species of mosquitoes known to occur in the state. His account of the common mosquitoes of Minnesota was recognized at the time published as being in no respect comprehensive but instead a summary of the information accumulated up to that time. After 1916, the mosquitoes of the state received little attention, and it was not until the present study was begun in 1932 that they again became the subject of research.

In recognition of their importance and the desirability of knowing more about the Minnesota species, this study was made an experiment station project in 1934.

ECONOMIC IMPORTANCE

Every insect which habitually feeds on the blood of man and large animals is not only important as a pest but is also a potential carrier of disease. In this respect mosquitoes are no exception. The blood-sucking habit has won for them greater recognition as vectors of disease than as irritating pests of the animal upon which they feed. Nevertheless, the pain and annoyance from their bite result in considerable discomfort to man and losses of a very definite nature to the stockman in Minnesota each season.

The effects of a mosquito bite differ among species and vary from individual to individual. A person may be very sensitive to the bite of one species and at the same time be relatively unaffected by another. The author had an opportunity to observe recently the reaction of a fellow student to bites of *Aedes communis* DeGeer. This person was repeatedly attacked by this species and after each bite there resulted a wheal of about three inches in diameter with subsequent swelling. Although he was bitten by *Aedes intrudens* Dyar and *Aedes stimulans* Walker simultaneously, only *communis* produced the severe skin re-

action. The author does not develop a skin reaction after the bite of any mosquito, yet there is considerable variation in the pain and irritation that may result from different species. For him the bites of *Aedes cinereus* Meigen and *Aedes intrudens* Dyar are painless, while those of *Aedes communis* DeGeer and *Aedes trivittatus* Coq., in particular, are very painful.

The annoyance to sportsmen, tourists, campers, the inhabitants of lake cottages, and others seeking outdoor recreation in the early spring and summer is considerable and of a nature difficult to express in quantitative terms. Yet, how often do we hear the familiar remark that a vacation spent at the lake or a picnic was spoiled by the mosquitoes. We have no way of determining how many tourists cut short their stay in mosquito-infested areas of the state each season or how many people are deterred from outdoor recreational activities owing to annoyance by these insects.

The money spent every year in the state for sprays and repellents is difficult to estimate. It amounts, however, to a considerable item. A conservative estimate on the annual cost of screening alone in Minnesota is $1,250,000.

Direct losses to the livestock industry of the state at the present time, as a result of mosquito attacks, are confined to irritation of animals, reduction in milk supply, and expense of spray materials. Although death among animals as a result of mosquito attacks did occur during the pioneer period, losses of this nature have not been suffered within recent years. It is doubtful if any of our native species will ever again become so numerous that their attacks will destroy domestic animals. On the other hand, such an outbreak of *Psorophora columbiae* Dyar and Knab did occur a few years ago in Florida (Bishopp, 1933). This species is normally not a serious pest in that state, yet, in this instance, it killed in the vicinity of Miami 80 cattle, 67 pigs, 3 horses, 1 mule, 20 fowls, and 2 dogs. It was suggested that in this particular outbreak a toxic substance of an obscure nature was the cause of death. The quantity of blood taken by a single mosquito at one meal is exceedingly small. However, in localities where several hundred individuals attack an animal simultaneously, the loss of blood over a period of weeks may be considerable. Stage and Yates (1936) have made careful estimates on the amount of blood consumed by *Aedes vexans* Meigen and *Aedes aldrichi* Dyar and Knab. These authors found that a population of mosquitoes with a maintained average of 500 adults feeding during the active hours would consume 23.92 cc., or approximately 0.05 pint of blood daily from one animal. The results of loss of blood and annoyance to animals are often of an insidious nature and difficult to detect. In northern Minnesota during the early spring, mosquitoes frequently become so abundant as to necessitate several applications daily of spray material on dairy cows. Washburn (1916) states: "Two years ago the mosquitoes were so numerous that they were quoted as the reason for increasing the price of milk."

DISEASE TRANSMISSION

That bloodsucking insects must be considered as possible factors in the transmission of every disease having the causative agent in the bloodstream has more and more come to be realized within the last few decades. Experimental proof of the role mosquitoes play in the transmission of such diseases as elephantiasis, malaria, and yellow fever dates from the period marking the close of the last century. It is beyond the scope of this work to treat even in a general way the etiology and symptomatology of the diseases known to be carried by mosquitoes. On the other hand, any consideration of the relation of the mosquitoes that occur in the state to the welfare of its people would be incomplete if the mosquito-borne diseases which are known to occur here were not emphasized.

That malaria was a rather common disease in Minnesota in the pioneer days and that it has been repeatedly brought into the state within recent years was emphasized by Riley (1930). Since Minnesota lies on the northern edge of the distribution of the disease in the United States, its presence in the state is rare. On the other hand, there are authentic records of the disease being contracted within the state, showing that when introduced it may be propagated during the warmest part of the summer. A significant fact in connection with its propagation is that there occur in Minnesota four species of the genus *Anopheles* which are known to be vectors.

Anopheles quadrimaculatus Say, the principal carrier of the disease in the southern and southeastern states, is present over much of the south and eastern half of the state, but is not common.

Anopheles maculipennis Meigen, the principal vector of the disease in Europe and California, is a common mosquito over much of the state east of the prairie counties.

Anopheles punctipennis Say, a demonstrated carrier but not so important in the southern states as *quadrimaculatus,* is fairly common over all the state exclusive of the northern forest.

Anopheles walkeri Theobald was shown by Matheson, Boyd, and Stratman-Thomas (1933) to be a good vector of the disease under experimental conditions. This mosquito has been taken from several parts of the state, but is not common.

With the demonstration that climatic conditions permit the propagation of malaria during the hottest part of the summer and with a mosquito fauna potentially available for its transmission, two factors point toward the sporadic recurrence of the disease within the state. These are: The careless use of induced malaria in the treatment of paresis patients, and the presence of malaria "carriers" among the tourist population who seek recreation in the state each summer.

The increase in incidence of equine encephalomyelitis in many parts of the United States during the last five years has attracted considerable

attention. The epidemiology of this disease had long pointed to the presence of an insect vector and, with the demonstration by Kelser (1933) and Merrill, Lacaillade, and Ten Broeck (1934) that the virus could be transmitted by three species of the genus *Aedes,* investigations on the role mosquitoes play in the spread of this disease were inaugurated in many parts of the United States. Of particular interest is the work done at the Utah Experiment Station and reported by Knowlton (1935), in which it was shown that *Aedes dorsalis* Meigen and *Aedes nigromaculis* Ludlow were capable of transmitting the virus from one animal to another. Since both of these species occur in Minnesota, it may have some bearing on the spread of the disease in this state. Unpublished data obtained from the Division of Veterinary Science, University Farm, St. Paul, show that this disease has been reported from every county of Minnesota except Aitkin, Cook, Koochiching, and Lake.

Fowl-pox, although as a rule not a highly fatal disease in poultry, may cause serious economic losses due to reduced egg-laying capacity in infected birds. Although the disease is transmissible by contact infection, its epidemiology has suggested an insect vector. Kliger, Muckenfuss, and Rivers (1929) have demonstrated that the infection can be transmitted by *Culex pipiens* L. and *Aedes aegypti* L. Matheson, Burnett, and Brody (1931) proved that the disease could be carried by *Aedes vexans* Meigen. Since *Aedes vexans* Meigen and *Culex pipiens* L. are both common mosquitoes in Minnesota, they doubtless play a role in the spread of the disease in this state.

The role that mosquitoes play in the transmission of tularemia was studied under experimental conditions by Philip, Davis, and Parker (1932). The results of this investigation indicate that mosquitoes which have fed on an animal infected with tularemia might infect persons mechanically (1) by biting, after having been interrupted during their meal on the infected animals, (2) by being crushed on the skin, and (3) by deposition of excrement on the skin. Since tularemia is a common disease among certain small animals in Minnesota, mosquitoes may play an important part in its transmission to man.

METHODS OF STUDY

The information obtained on the species of mosquitoes found in Minnesota, their habits, life histories, and distribution within the state, was secured by collecting and rearing larvae and also by collecting adults in the field. Any adequate survey of the mosquitoes characteristic of a particular locality must be based on both larval and adult records as not all species develop at the same rate. Since different species appear at varying intervals during the season, continual field observations must be made in order to obtain a complete picture of the seasonal cycle for each. The problem as developed has been largely a field study pursued

for the purpose of learning what species of mosquitoes are present, where they are found, how they live, and their importance in Minnesota.

Larvae were taken from the pools in which they occur and transported to the laboratory in pint jars. Each sample of larvae from a particular kind of pool or habitat was given a key number. Field notes giving the locality, date, nature of the water, size of the pool, character of the environment, etc., in which the larvae occurred were recorded and filed under the corresponding key number. Each collection of larvae from a particular pool was kept separate after being brought into the laboratory, and, with few exceptions, all rearing was done in the pint containers used to transport them. Upon emergence, the adults were permitted to die in a cage or were taken from the culture jars and killed when they were from 24 to 36 hours of age.

Each adult, when pinned, was given the key number of the culture from which it came and, when identified, its species was recorded in the permanent records under the corresponding number. In a few instances, identifications were made from preserved larvae, but whenever possible these were reared through to the adult stage.

The rearing of isolated larvae in small vials was practiced, but not extensively as it required considerable time. The larval skins obtained in this manner were frequently used in checking the identity of certain species.

The male hypopygium has been used extensively in making identifications and was found especially valuable in those instances where adults were rubbed.

Extensive observations have been made in every part of the state during different periods of the spring and summer. Field trips extending over a period of three or four days were made to parts of the state remote from St. Paul. During the summer of 1934, a field base was established at the Cloquet Forest Experiment Station where five weeks of intensive work was done. Here the fauna characteristic of the cold pools of the northern forest was studied.

II. ECOLOGICAL RELATIONSHIPS

TOPOGRAPHY AND CLIMATE OF MINNESOTA

Topography.—Minnesota embraces an area of 84,682 square miles and is located near the center of the North American Continent. Its greatest length is nearly 400 miles, extending from the northern boundary of Iowa to a point known as the Northwest Angle slightly beyond the 49th parallel.

Much of the surface features of the state can be traced to the periods of intense glacial activity. The flat, northwest corner was once the bed of the glacial Lake Agassiz. The roughest part of the state is the northeast quarter; although glaciated, the early geologic formations were not

obliterated. The undulating and hilly surfaces of central and southern Minnesota are directly traceable to successive ice sheets which overspread the state. Standing water is a prominent feature, occupying the basins among the moraine ridges and knolls and on the outwash plains left by the receding ice. Many of these bodies of water can be classified as lakes, while others represent small, shallow ponds, marshes, and swamps.

The drainage of the state goes into three great systems, about 57 per cent leading to the Gulf of Mexico, 34 per cent to the Hudson Bay, and 9 per cent to the St. Lawrence River. The streams of these several drainage systems are so interwoven in the north central part of the state, there being no prominent dividing ridges to separate them, that in many cases a swamp or lake may drain either into the Hudson Bay or the Gulf of Mexico.

With the surface dotted with natural depressions and large areas of the northern forest poorly drained, Minnesota presents ideal conditions for a rich and plentiful mosquito fauna.

Climate.—The climate of Minnesota is classed as continental, meaning that the temperature extremes are greater and the humidity and rainfall generally less than at places bordering on oceans. The large bodies of water in the state have a local effect in modifying the extreme heat in the summer.

The mean annual temperature of the state ranges from approximately 35° F. on the northern border to approximately 45° F. in the extreme southeast corner. The extremes in temperature are very great, ranging from a minimum of −59° F. at Leech Lake to a maximum of 109° F. at Red Lake as local records. These extremes in temperature may materially affect the population of certain species, as was observed during the severe winter of 1935-36, when hibernating adults of three species were found frozen. That periods of extreme heat with low humidity shortens the lives of adults is borne out both by field observations and laboratory experience.

The precipitation varies not only from month to month, but differs in the several regions of the state. The average annual precipitation is 26+ inches, being from one-fourth to one-third greater along the eastern boundary than along the western boundary. June and July are the wettest months, while there is normally the least precipitation in February. The amount of rainfall is probably a determining factor in the distribution of many species, and it may, under local conditions, materially alter the abundance of adults.

During the period of severe drought in the early spring of 1934, young larvae were found in many temporary pools in which the water evaporated before they had time to mature. The abundance of those species in which there are several generations, or in which a portion of the eggs hatch with successive wetting and drying, is determined by the amount and frequency of precipitation.

VEGETATIONAL REGIONS

Any discussion of the bionomics of mosquitoes must inevitably lead to a consideration of the gross vegetational regions of the area under consideration. Just why the mosquito fauna of a tamarack swamp should differ from that of the open prairie is not clear, yet each has its characteristic species.

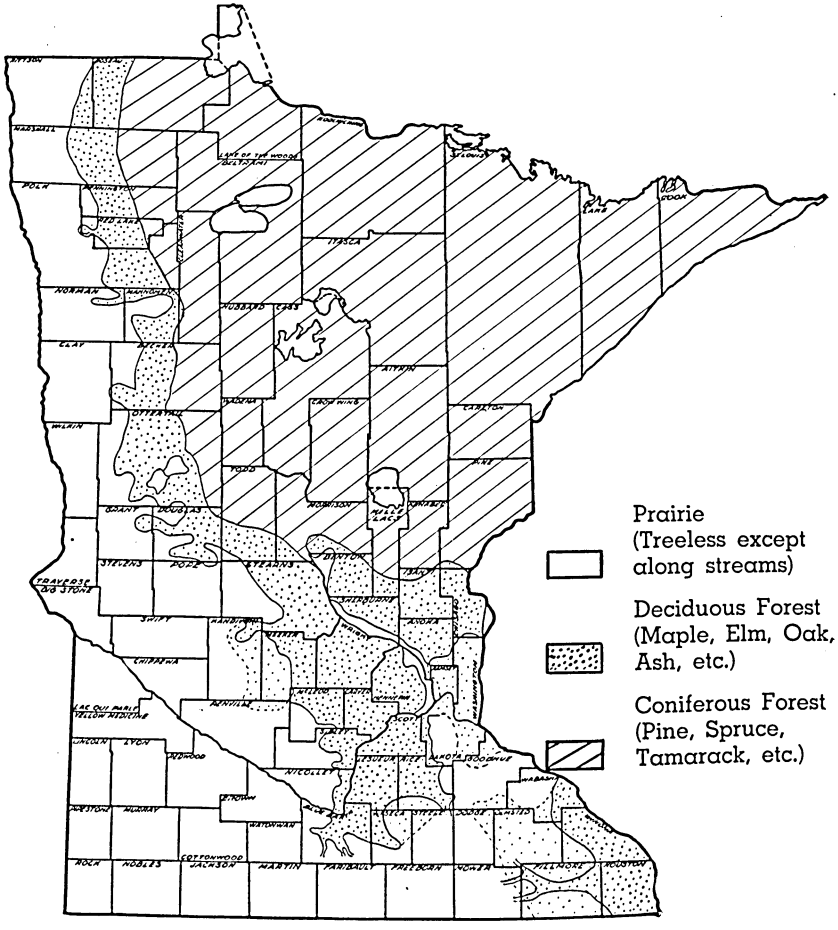


Fig. 1. Vegetational Regions of Minnesota
(Taken from Rosendahl and Butters' "Trees and Shrubs of Minnesota," University of Minnesota Press, 1928)

With respect to vegetation, Minnesota may be divided into three great regions. There were originally the coniferous forest, the deciduous forest, and the prairies (Fig. 1).

The Coniferous Forest.—This region originally extended over the northeastern one-third of the state, reaching to a line about half

way between Duluth and Minneapolis and west to the Red River Valley. The upland part of the evergreen forest is characterized by the presence of pines, white spruce, balsam fir, and white birch, while the swamps contain black spruce, tamarack, and white cedar. Other deciduous trees in addition to white birch are balsam, poplar, aspen, red maple, etc. Excessive lumbering and fires have eliminated the original evergreens over large areas, resulting at the present time in a vegetation in the birch-poplar stage. With the removal of the timber, large areas outside the National Forests were diverted to agricultural uses.

The Deciduous Forest.—The deciduous forest occupied a strip across the state from the southeast to the northwest, forming a line between the prairies and evergreen forest. The vegetation of this region varied somewhat, but was characterized mainly by oaks, basswood, elms, hickory, maple, etc. Much of these woods still remains in the form of groves and private woodlots.

The Prairies.—The prairies are restricted to the southern and western part of the state. The woody vegetation consisted of isolated prairie groves, bottomland forest along streams, and the woody vegetation of the prairie proper, such as the prairie wild rose. The prairie region is largely under cultivation today.

LARVAL HABITATS AND ASSOCIATIONS

There is a definite tendency for mosquitoes to show a preference for breeding in waters of a particular character. Some species are so restricted in this respect that the larvae are always found in certain unique habitats, while others are less selective, the larvae being found in a variety of situations. So little is known about the oviposition responses of mosquitoes that one can not say whether the eggs in many species are deposited only in certain places or whether the females scatter them about promiscuously. Field experience would lead one to believe that even in the more general breeders the females do exercise a certain amount of selection in seeking places to oviposit.

Within recent years, the physical and chemical properties of the water in which larvae are found have been investigated by Senior-White (1926), Rudolfs (1928), and others. The results obtained in these studies indicate that it is very difficult to select any one chemical constituent or group of constituents of the medium and attribute the presence or absence of a species to these factors alone. Larvae of most species show a rather wide tolerance to variations in the chemical nature of their water habitats.

In this study, attention was devoted only to the gross environmental factors as they relate to the presence of larvae of different species. Larvae were taken from some three hundred different habitats (forest pools, rain pools, etc.) located in all parts of the state. Since the larvae from each habitat were kept separate, it has been possible to show under what conditions each species may be found. In order to facilitate present-

ing these data in concise form, these habitats have been grouped into 13 different types:

A. Semipermanent and Permanent Ponds.—Larvae usually found around the shoreline in water six to eight inches in depth. These ponds are more often in full sunlight and have a growth of aquatic plants and algae especially around the margins. There is usually some dead vegetation around the margins, representing the remains of the last season's plant growth.

B. Marshes.—Under this heading are classified marshy areas around lakes, ponds, or the flood plains of rivers and old lake beds. The characteristic vegetation is such marsh plants as sedges, cattails, and iris. The water is shallow, often in small pools, and in late summer may become stagnant.

C. Temporary Pools.—These small pools are, as a rule, several feet in diameter, with the water 6 to 15 inches in depth. Small depressions such as cow tracks also come under this heading. These are in exposed, unshaded places, as along highways, or in fields. The source of the water is from melting snow in the early spring and from rain later in the season. These are often quite turbid and contain considerable decaying grass on the bottom.

D. Woodland Pools.—These are temporary pools of varying sizes and depths and are always shaded by deciduous trees. The floor of the pool usually is covered with a mat of decaying leaves, and there are often aquatic plants around the margins. The source of the water is from melting snows and rains. These habitats are located in groves, woodlots, and hardwood forests.

E. Coniferous Forest Pools.—These are cold, shaded pools of varying size which occur in the tamarack and spruce swamps of the northern forest. The temperature of the water varies with the density of the swamp, but, in many instances, it is never warmer than 10° C. while the larvae are developing. The water often disappears from these habitats in late summer, but they seldom become thoroughly dry. Sphagnum moss is usually a constant feature in these waters and there may be some decaying vegetation from various sources.

F. Bogs.—Under this type are classified the more open bogs that are common in the northern part of the state. These have a sphagnum mat and quite frequently a coverage of low shrubbery. They are often the quaking bogs around lakes. The water is cold, shallow, and for the most part unshaded.

G. Foul Stagnant Pools.—These highly stagnant waters are more often contaminated by drainage from barnyards.

H. Lakeshores.—Small inlets or pools having a connection with the main body of the lake, or the margin of the lake proper.

I. Streams.—Under this heading are listed streams of various sizes in which there was a definite flow of water at the time the larvae were taken. In every instance that larvae were found in running water

they were along the margin where there was grass and little movement of the water.

J. Artificial Receptacles.

K. Treeholes.

L. Potholes.—These are holes in the rocks along rapids in streams and on lakeshores that are the result of water erosion. They vary in size from a few inches to two or three feet in diameter and are only a few inches in depth. The water may be derived either from the stream during flood stage or from the rain.

M. Leaves of Plants.—The pitcher plant is the only representative of this type of habitat to be found in the state.

Table 1. Occurrence of Larvae by Species and Type of Habitat

Species	Type of Habitat*												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Aedes atropalpus Coq.											3		
Aedes aurifer Coq.			2			1							
Aedes campestris D. and K.		1	2				1						
Aedes canadensis Theo.	2	2	18	10	23	5							
Aedes cinereus Meigen	4	10	20	15	24	9		2					
Aedes communis DeGeer			3	2	13	1							
Aedes diantaeus H., D., and K.					7	1							
Aedes dorsalis Meigen			2				1						
Aedes excrucians Walk.	1	2	7	4	5	1		1					
Aedes fitchii F. and Y.	4	2	4	4		3							
Aedes flavescens Müller	1	3	1	1									
Aedes hirsuteron Theo.			1		1								
Aedes impiger Walker			2	5	3	1							
Aedes intrudens Dyar	1	2	1	3	1	2							
Aedes nigromaculis Lud.							1						
Aedes punctor Kirby		2	1	4	22	4			1				
Aedes spencerii Theo.		1	2										
Aedes stimulans Walk.	1	1	8	9	1								
Aedes trichurus Dyar					1	1							
Aedes triseriatus Say												4	
Aedes vexans Meigen	2	7	15	3	4		4						
Anopheles maculipennis Meig.	11	2	2	1		2			2				
Anopheles punctipennis Say	7	2	5						1				
Anopheles quadrimaculatus Say	2			1									
Anopheles walkeri Theo.	1		1						1				
Culex apicalis Adams	9	10	3	2	1	3							
Culex pipiens Linnaeus										2			
Culex salinarius Coq.	2	2	2			1				1			
Culex tarsalis Coq.	14	9	21	6		2	4	2					
Culex territans Walk.	4	10	6	4	2		1			1			
Taeniorhynchus perturbans Walk.						1							
Theobaldia inornata Williston	3	12	11	5	1	1		1					
Theobaldia morsitans Theobald		1	2		3								
Uranotaenia sapphirina O. S.	3	2	2			1							
Wyeomyia smithii Coq.													6

* Description of habitats given on pp. 11, 12, and 13.

The data given in Table 1 show the number of times each species was found in the various habitats. Although the figures are small in many instances, they do illustrate some significant facts. In the first

place, the majority of the species are to be found in the first six habitats, and "temporary pools" leads the list with a total of 26 different species. A second and perhaps more significant fact is that the larvae of such species as *Aedes cinereus* Meigen, *Aedes canadensis* Theo., *Aedes excrucians* Walker, *Culex tarsalis* Coq., *Theobaldia inornata* Willis., *Aedes vexans* Meigen, and *Culex apicalis* Adams are found in a variety of habitats, whereas *Aedes communis* DeGeer, *Aedes diantaeus* H., D., and K., *Aedes impiger* Walker, *Anopheles punctipennis* Say, and *Theobaldia morsitans* Theo. appear to be more restricted.

When the four most unique habitats—pitcher plants, treeholes, artificial receptacles, and potholes—are eliminated from the list, there remains only the forest-pool habitat with a definite fauna of its own. The species rather sharply limited to these waters are: *Aedes communis* DeGeer, *Aedes diantaeus* H., D., and K., *Aedes punctor* Kirby, *Theobaldia morsitans* Theo., and possibly *Aedes trichurus* Dyar. Although many of the other species occur more often in certain habitats, one can hardly select a strictly woodland pool, marsh, or pond group.

The great range in larval habitats of most species is emphasized in Table 2, showing association of larvae. The figures represent the number of times the larvae of each species were taken together with the others. Species which select the same types of habitats and whose larvae develop at the same time are more often found associated. Those that have a wide range of larval habitats would naturally be associated with the greatest number of other species. There are no records for the United States species with which the figures in Table 2 can be compared. The association values for two species certainly would vary in different parts of their range, depending upon the relative abundance of each.

That the association of species in a particular habitat is determined by certain ecological factors of an obscure nature, but, nevertheless, fundamental to the problem of occurrence of larvae and even their distribution, was pointed out by Senior-White (1920). The excellent work of Senior-White (1926) on the analysis of physical and chemical factors as related to breeding of larvae was, likewise, based on this assumption: "In my opinion, these associations are fundamental. In the reasons which underlie them are hidden everything that has any bearing on the bionomics of each species; in other words, they represent the product of the interaction of all the physical and chemical factors which it is the object of the present research to elucidate in measurable terms."

These authors were working in the Far East under conditions entirely different from those of the northern United States. The habitat associations there are apparently more definite than those observed in Minnesota.

The absence of clear-cut habitat associations among the more general breeders outside the northern swamps may be the result of two conditions. In the first place, the mosquito faunas of the state contain many

Table 2. Occurrence of Larval Association

	Aedes aurifer Coq.	*Aedes campestris* D. & K.	*Aedes canadensis* Theo.	*Aedes cinereus* Meigen	*Aedes communis* DeGeer	*Aedes diantaeus* H., D., & K.	*Aedes dorsalis* Meigen	*Aedes excrucians* Walk.	*Aedes fitchii* F. & Y.	*Aedes flavescens* Müller	*Aedes hirsuteron* Theo.	*Aedes impiger* Walker	*Aedes intrudens* Dyar	*Aedes nigromaculis* Lud.	*Aedes punctor* Kirby	*Aedes spencerii* Theo.	*Aedes stimulans* Walk.	*Aedes trichurus* Dyar	*Aedes vexans* Meigen	*Anopheles maculipennis* Meig.	*Anopheles punctipennis* Say	*Anopheles quadrimaculatus* Say	*Anopheles walkeri* Theo.	*Culex apicalis* Adams	*Culex pipiens* Linnaeus	*Culex salinarius* Coq.	*Culex tarsalis* Coq.	*Culex territans* Walk.	*Taeniorhynchus perturbans* Walk.	*Theobaldia inornata* Willis.	*Theobaldia morsitans* Theo.	*Uranotaenia sapphirina* O. S.
Aedes aurifer Coq.	.....	.....	1	3	.....	.....	.....	1	2	.....	.....	1	.....	.....	1	.....	1	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aedes campestris D. & K.	.....	2	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
Aedes canadensis Theo.	1	.....	9	31	7	3	.....	7	5	1	2	2	3	.....	17	1	3	1	4	.....	.....	.....	.....	.....	.....	3	4	.....	6	6	.....
Aedes cinereus Meigen	3	.....	31	12	8	3	1	13	9	2	1	7	6	.....	22	.....	4	1	11	.....	.....	.....	.....	3	.....	3	6	1	12	5	.....
Aedes communis DeGeer	.....	.....	7	8	1	5	.....	2	2	.....	.....	3	1	.....	9	.....	.....	1	2	.....	.....	.....	.....	.....	.....	.....	1	1	.....	.....	.....
Aedes diantaeus H., D., & K.	.....	.....	3	3	5	.....	.....	.....	.....	.....	.....	1	1	.....	6	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....
Aedes dorsalis Meigen	.....	2	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
Aedes excrucians Walk.	1	.....	7	13	2	.....	.....	.....	5	2	.....	1	.....	.....	5	.....	4	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	5	.....	.....
Aedes fitchii F. & Y.	2	.....	5	9	2	.....	.....	5	.....	1	.....	1	1	.....	3	.....	4	.....	5	.....	.....	.....	.....	.....	.....	.....	.....	1	2	.....	.....
Aedes flavescens Müller	.....	.....	1	2	.....	.....	.....	2	1	.....	.....	1	1	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	2	.....	3	.....	.....
Aedes hirsuteron Theo.	.....	.....	2	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....
Aedes impiger Walker	1	.....	2	7	3	1	.....	1	1	1	.....	.....	.....	.....	4	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aedes intrudens Dyar	.....	.....	3	6	1	1	.....	.....	1	1	.....	.....	1	.....	3	.....	.....	1	2	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....
Aedes nigromaculis Lud.	.....	1	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
Aedes punctor Kirby	1	.....	17	22	9	6	.....	5	3	.....	1	4	3	.....	8	.....	.....	1	2	.....	.....	.....	.....	1	.....	.....	2	1	.....	4	.....
Aedes spencerii Theo.	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aedes stimulans Walk.	1	.....	3	4	.....	.....	.....	4	4	.....	1	1	.....	.....	1	.....	3	.....	1	.....	.....	.....	.....	.....	.....	2	.....	.....	2	.....	.....
Aedes trichurus Dyar	.....	.....	1	1	1	.....	.....	.....	.....	.....	.....	.....	1	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aedes vexans Meigen	1	1	4	11	2	2	2	4	5	2	.....	.....	2	1	2	.....	1	.....	13	.....	.....	.....	.....	3	2	.....	4	.....	.....	.....	.....
Anopheles maculipennis Meig.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	3	1	.....	4	.....	.....	.....	.....	.....	.....	.....
Anopheles punctipennis Say	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	1	2	.....	5	.....	5	1	.....	.....	.....	5
Anopheles quadrimaculatus Say	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	2	.....	.....	5	.....	1	8	2	.....	.....	2
Anopheles walkeri Theo.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Culex apicalis Adams	.....	.....	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	4	5	.....	1	7	.....	6	7	7	.....	6	.....	4
Culex pipiens Linnaeus	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	1	.....	.....	.....	.....
Culex salinarius Coq.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	1	6	1	.....	2	.....	1	.....	.....	.....
Culex tarsalis Coq.	1	3	3	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	2	.....	3	5	8	.....	1	7	.....	26	9	.....	11	.....	3
Culex territans Walk.	.....	.....	4	6	1	.....	.....	.....	2	.....	.....	.....	1	.....	2	.....	.....	.....	2	1	2	.....	.....	7	1	2	9	3	.....	5	.....	2
Taeniorhynchus perturbans Walk.	.....	.....	.....	1	1	.....	.....	.....	1	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Theobaldia inornata Willis.	.....	.....	6	12	.....	.....	.....	5	2	3	.....	.....	.....	.....	.....	.....	2	.....	4	.....	.....	.....	.....	6	.....	1	11	5	.....	4	1	.....
Theobaldia morsitans Theo.	.....	.....	6	5	.....	1	.....	.....	.....	.....	1	.....	.....	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....
Uranotaenia sapphirina O. S.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5	2	.....	.....	4	.....	.....	3	2	.....	.....	.....	.....

species that are rather cosmopolitan in distribution; namely, *Aedes vexans* Meigen, *Theobaldia inornata* Williston, *Aedes cinereus* Meigen, *Culex territans* Walker, *Aedes excrucians* Walker, and others. One would expect these widely distributed species, in the absence of local races, to be less selective in their breeding habits than those more restricted in distribution. The second factor which may throw some light on the absence of well-defined habitat associations is the original distribution of the coniferous forest, deciduous forest, and prairies in the state. Minnesota in a sense represents the meeting place of these major vegetational areas. With the development of agriculture and the lumber industry, the dividing lines between these areas have been obliterated in many parts of the state. There is no longer the sharp break between forest and prairie and, likewise, the break between deciduous and coniferous forests is obscure, except in isolated localities. The prairie species have always invaded the forest to a limited degree, and the fauna of the coniferous and deciduous forest was probably never distinct. Nevertheless, the conversion of the prairies into an agricultural area and the excessive lumbering in both the deciduous and hardwood forests have more and more brought about an overlapping of the mosquito faunas of these respective areas.

The distribution maps of several species are of particular interest in that they suggest the present distributon in the state as related to the early vegetational areas (Figs. 4-11).

III. BIOLOGY AND TAXONOMY

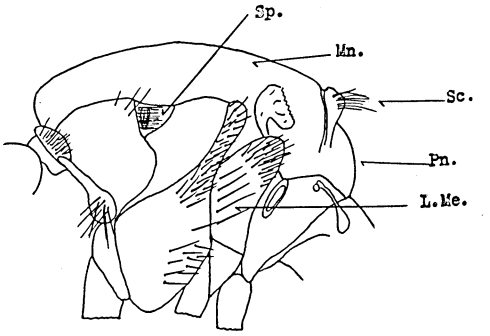
EXTERNAL CHARACTERS USED IN THE IDENTIFICATION OF MOSQUITOES

A brief summary of the more technical characters is here presented. For a more detailed account of the morphology of mosquitoes, the reader is referred to Matheson (1929).

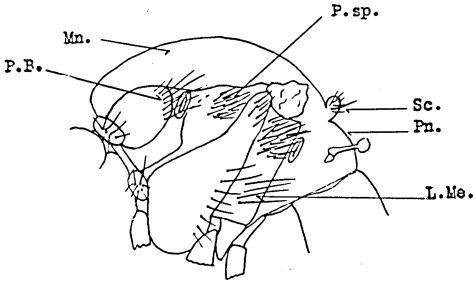
Adult.—The head is globose and bears the large, compound eyes, antennae, and mouthparts. The proboscis consists of the labium and labrum-epipharynx which enclose the hypopharynx, mandibles, and maxillae. The principal characters on the head consist of the proboscis, maxillary palpi, occiput, nape, and cheeks. In the female the proboscis is fitted for piercing and sucking and the maxillary palpi are usually short, consisting of three to five segments. In the males the proboscis is more flexible and not fitted for piercing. The maxillary palpi are elongated, reaching to the end of the proboscis. The occiput is the region on the dorsal side of the head between the eyes. The nape is posterior to the occiput. The color and structure of the scales on the occiput are widely used. The cheeks are represented by the region on the sides of the head posterior to the eyes.

The thorax (Plate 1) bears many good taxonomic characters. The most conspicuous part of this region is the large shield-like mesonotum located on the dorsal side. The scales of the mesonotum are variable in color, presenting in many instances distinct patterns. Where these have not been rubbed off, the coloration of this region affords a means of separating many species. Posterior to the mesonotum and separated from it by a suture is the scutellum. In all the genera except *Anopheles* the scutellum is trilobed and each lobe bears a group of bristles. In *Anopheles* the scutellum is crescent-shaped with setae around the margin. The region behind the scutellum is the postnotum. It is nude and smooth except in *Wyeomyia* where it bears a patch of bristles near the posterior margin. The sides of the thorax are usually covered with scales which differ in color among species. The sclerites on the sides of the thorax bear groups of bristles that are valuable in separating genera and certain species.

The wings are fringed with scales and the wing veins also bear scales. These scales are often colored and may present definite patterns. The wing veins and the cells are designated in



1.



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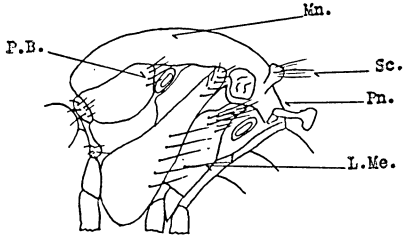

3.

Plate 1. Lateral View of the Thorax of:

1. *Theobaldia inornata* Williston
2. *Aedes impiger* Walker
3. *Culex tarsalis* Coquillett

L.Me—Lower mesepimeral bristles
Mn.—Mesonotum
P.B.—Prothoracic bristles
P.sp.—Post-spiracular bristles
Pn.—Postnotum
Sp.—Spiracular bristles
Sc.—Scutellum

the keys and in the descriptions of species according to the Comstock-Needham terminology.

The legs are long, slender, and made up of the usual parts—coxa, trochanter, femur, tibia, and tarsus. The tarsi have five joints and the segments may be very long. The scales on the tarsi vary in color among species, and, in many cases, produce distinct bands.

The abdomen is long, slender, and covered with scales. The coloration of these scales is variable among species, frequently resulting in distinct bands. The first eight segments of the abdomen are uniformly alike, but the ninth and tenth segments are greatly modified to form the genitalia. The male genitalia or hypopygium affords the most

Fig. 2. Hypopygium of *Aedes spencerii* Theobald

A.L.—Apical lobe
B.L.—Basal lobe
Cl.—Clasper
Cs.—Claspette
F.Cs.—Filament of claspette
Mes.—Mesosome
L.9—Lobes of the ninth tergite
10 S.—Tenth sternite
S.P.—Side-piece

critical taxonomic characters available on the adult mosquito. Unfortunately, this part must be removed from the specimen and given special treatment before the structures are visible for study. The hypopygium of *Aedes spencerii* Theobald is shown in Figure 2. The genitalia of this species is typical of the genus *Aedes*. The hypopygia of the other genera differ somewhat; however, the homologous parts can be located with little difficulty. For diagrams of the hypopygia of North

American species, the reader is referred to Dyar (1928) and Matheson (1929).

Larva.—The larval characters of *Aedes excrucians* Walker, as illustrated in Figure 3, are typical for all the Minnesota species except the *Anopheles*. In the genus *Anopheles* the siphon is lacking and some of the abdominal segments bear paired tufts of float hairs on the dorsal surface.

SYSTEMATIC TREATISE

Mosquitoes are two-winged flies belonging to the order Diptera, family Culicidae, and, as used in this study, are restricted to the sub-family Culicinae. They may be described, therefore, as delicate, soft-bodied flies in which the thorax is ovate, arched but not projecting over the head, without a V-shaped suture; scutellum short, rounded, or trilobate; postnotum arched; and with body and appendages more or less covered with scales. Wings long, slender, six well-developed veins, the margin fringed with scales, media two-branched, costa reaching around margin; wing veins bearing scales. Mouthparts of female fitted for piercing and sucking; mouthparts of male well developed, but too delicate for piercing and none are

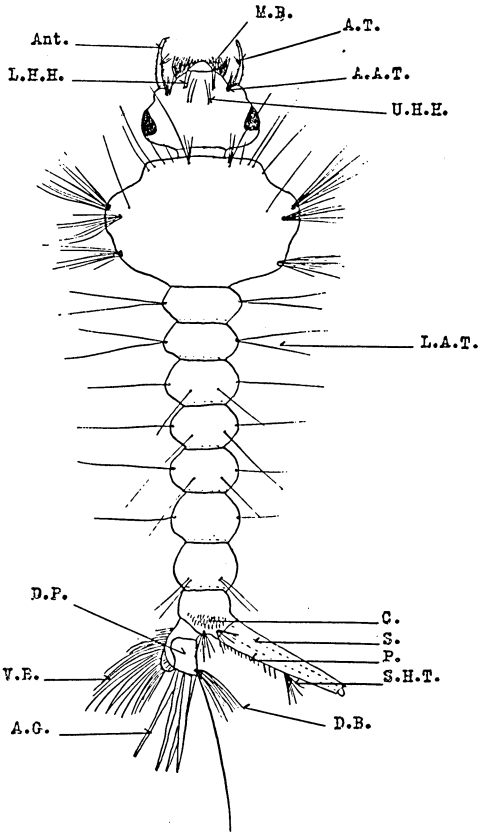

Fig. 3. Dorsal View of the Larva of *Aedes excrucians* Walker

Ant.—Antenna
A.T.—Antennal tuft
A.A.T.—Anteantennal hair tuft
A.G.—Anal gills
C.—Comb
D.B.—Dorsal brush
D.P.—Dorsal plate
L.A.T.—Lateral abdominal tufts
L.H.H.—Lower head hairs
M.B.—Mouth brushes
P.—Pecten
S.—Siphon or air-tube
S.H.T.—Siphonal hair tuft
U.H.H.—Upper head hairs
V.B.—Ventral brush

known to suck blood. The larvae are aquatic, and the pupae are also aquatic and active.

Two types of keys are presented for the identification of the Minnesota species. The first is a non-technical key for adults and is based on characters that are rather easily recognized. With the aid of a hand lens or binocular microscope, most of the species may be identified readily with this key. Since it is based largely on coloration, it is essential that as few of the scales be rubbed off as possible. The second series of keys are based on more technical characters and for their successful use one should be equipped with a binocular microscope that gives a high magnification. Here again, it is essential that the scales and bristles be kept intact on the specimen.

It should be pointed out that the keys for identification of adults are more satisfactory when used to determine the identity of the females than for males. The scales of the males are often duller with less contrast in the color patterns of the wings and thorax. Although the hypopygia require special treatment before the characters are visible for taxonomic use, they afford a sure check of the identity of males and are an indispensable adjunct in instances where males otherwise are marred beyond recognition.

The advantages of making larval identifications from mature larvae, either alive or preserved, and from their cast skins is too well known to warrant further discussion.

After the name of each species a brief list of recognition characters is given. These are to be used as aids in making determinations and must not be interpreted as representing a complete description of the species.

In making identifications of species in the course of this work, the author has made free use of Dyar (1928) and Matheson (1929). Both of these excellent works have been indispensable. Since these authors are not in agreement in regard to the proper use of certain generic and specific names, the writer has adopted, rather by choice, the terminology of Matheson. With respect to the identification of the mosquitoes in this state, the author has found the keys of Matheson (1929) wholly satisfactory. With the permission of the author and his publisher they have been adapted for use in the present work.

SPECIES OF MOSQUITOES FOUND IN MINNESOTA

Thirty-seven species of mosquitoes are now known to occur in Minnesota. These are distributed among seven genera. For ready reference the complete list is here given:

Aedes atropalpus Coquillett
Aedes aurifer Coquillett
Aedes campestris Dyar & Knab
Aedes canadensis Theobald
Aedes trichurus Dyar
Aedes triseriatus Say
Aedes trivittatus Coquillett
Aedes vexans Meigen

Aedes cinereus Meigen
Aedes communis DeGeer
Aedes diantaeus Howard, Dyar, & Knab
Aedes dorsalis Meigen
Aedes excrucians Walker
Aedes fitchii Felt & Young
Aedes flavescens Müller
Aedes hirsuteron Theobald
Aedes impiger Walker
Aedes intrudens Dyar
Aedes nigromaculis Ludlow
Aedes punctor Kirby
Aedes riparius Say
Aedes spencerii Theobald
Aedes stimulans Walker
Anopheles maculipennis Meigen
Anopheles punctipennis Say
Anopheles quadrimaculatus Say
Anopheles walkeri Theobald
Culex apicalis Adams
Culex pipiens Linnaeus
Culex salinarius Coquillett
Culex tarsalis Coquillett
Culex territans Walker
Taeniorhynchus perturbans Walker
Theobaldia inornata Williston
Theobaldia morsitans Theobald
Uranotaenia sapphirina Osten Sacken
Wyeomyia smithii Coquillett

KEYS FOR THE IDENTIFICATION OF MINNESOTA MOSQUITOES

Simple Recognition Key

1. Proboscis of female ringed with white 2
   Proboscis of female not ringed with white 4
2. Abdomen with dorso-median longitudinal white line ..... *Aedes nigromaculis*
   Abdomen without a distinct dorso-median white line 3
3. Tarsi with white rings on both ends of the joints ..... *Culex tarsalis*
   Tarsi with white rings on basal ends of joints only ..... *Taeniorhynchus perturbans*
4. Wing scales forming dark and light areas, thus producing more or less distinct spots 5
   Wing scales never producing spots, although they may be bi-colored 7
5. Wings with two yellowish spots on the costal margin ..... *Anopheles punctipennis*
   Wings without such markings 6
6. Yellowish spot at apex of wing ..... *Anopheles maculipennis*
   Apex of wing uniformly dark colored ..... { *Anopheles walkeri* / *Anopheles quadrimaculatus*
   (For differentiation see technical key)
7. Abdomen uniformly colored, not banded 8
   Abdomen with segmental white bands, or with lateral or dorso-median white spots 11
8. Abdomen covered with yellowish scales; a large yellowish species ..... *Aedes flavescens*
   Abdomen without such markings 9
9. Abdomen covered with white scales ..... *Aedes spencerii*
   Abdomen covered with dark scales 10

10. Postnotum with a tuft of setae ..... *Wyeomyia smithii*
    Postnotum without a tuft of setae ..... *Culex salinarius*
11. Abdomen with lateral or median white spots; without transverse white bands 14
    Abdomen with transverse white bands 14
12. Abdomen with median white spots. Thorax and wings with patches of blue scales ..... *Uranotaenia sapphirina*
    Abdomen with lateral white spots. Thorax and wings without blue scales 13
13. Mesonotum dark brown in the middle, silvery-white on the sides ..... *Aedes triseriatus*
    Mesonotum with a dark-brown median line, a broad, yellowish stripe on either side ..... *Aedes trivittatus*
    Mesonotum with broad, dark, median stripe, narrow, yellow line on either side ..... *Aedes aurifer*
14. White bands of abdomen on apical ends of the segments ..... *Culex apicalis*
    White bands of abdomen on basal ends of the segments 15
15. White bands of abdomen uniting in middle to form a dorsomedian stripe 16
    White bands of abdomen separate, never uniting 17
16. Wing scales uniformly black and white intermixed *Aedes campestris*
    Vein R4+5 of wings entirely dark-scaled, others black and white intermingled ..... *Aedes dorsalis*
    Wing scales all white except on veins R, R4+5, Cu_1 and Cu_2 which are black ..... *Aedes spencerii*
17. Tarsal joints ringed with white 18
    Tarsal joints not ringed with white 22
18. Tarsi with white rings on both ends of joints 19
    Tarsi with white rings on basal ends of joints only 20
19. Tarsal rings very narrow. Mesonotum clothed with reddish-brown and yellowish-white scales intermingled; two bare submedian stripes ..... *Theobaldia morsitans*
    Tarsal rings distinct. Mesonotum uniformly reddish-yellow ..... *Aedes canadensis*
    Tarsal rings distinct. Mesonotum with broad, dark, median stripe, yellowish on the sides ..... *Aedes atropalpus*
20. Tarsal white rings very narrow ..... *Aedes vexans*
    Tarsal white rings broad, especially on the hind legs 21
21. Mesonotum entirely reddish-brown ..... *Aedes riparius*
    Mesonotum reddish-brown in middle or with a distinct, brown, median line, light on the sides. The coloration somewhat variable ..... *Aedes fitchii*, *Aedes excrucians*, *Aedes stimulans*
22. Mesonotum uniformly dark or with light patches 23
    Mesonotum with one or two longitudinal stripes 27

23. Wing scales black and white intermingled on the costal margin. A large species ..... *Theobaldia inornata*
Wing scales uniformly dark 24
24. Lateral white spots of abdomen uniting to form a continuous line ..... *Aedes cinereus*
Abdomen without such markings 25
25. Post-spiracular bristles present ..... *Aedes intrudens*
Post-spiracular bristles absent 26
26. Mesonotum uniformly clothed with narrow, dark-brown scales ..... *Culex pipiens*
Mesonotum clothed with brown scales, with small patches of white scales along the anterior margin and above the roots of wings ..... *Culex territans*
27. Mesonotum with a single median stripe 28
Mesonotum with paired median lines 29
28. Mesonotum with a broad, golden brown median stripe; sides yellowish ..... *Aedes hirsuteron*
Mesonotum with a dark-brown, median stripe; sides reddish-brown ..... *Aedes punctor*
Mesonotum with broad, dark-brown median stripe, often intermingled with gray scales; sides grayish-white ..... *Aedes trichurus*
29. Paired median lines dark, separated by a narrow, yellow line; sides yellowish-gray ..... *Aedes communis*
Paired median lines dark, separated by a broad, yellowish-brown line; sides white ..... *Aedes impiger*
Mesonotum bronzy-yellow; two narrow, dark median lines ..... *Aedes diantaeus*

Technical Keys[2]

Key to the Genera

ADULTS

1. Scutellum crescent-shaped, never trilobed, with the marginal setae evenly distributed ..... *Anopheles*
Scutellum trilobed, the marginal setae on the lobes only 2
2. Postnotum with a tuft of setae ..... *Wyeomyia*
Postnotum without a tuft of setae 3
3. Wings with cell R2 not half as long as its petiole ..... *Uranotaenia*
Wings with cell R2 more than half as long as its petiole 4
4. Spiracular bristles present ..... *Theobaldia*
Spiracular bristles absent 5
5. Post-spiracular bristles present ..... *Aedes*
Post-spiracular bristles absent 6

[2] Adapted from Matheson's "Handbook of the Mosquitoes of North America," through the courtesy of Charles C. Thomas, Publisher, Springfield, Illinois, and Prof. Robert Matheson, Cornell University.

6. Lower mesepimeral bristles 1, rarely 2 ..... *Culex*
   Lower mesepimeral bristles 3 or 4 ..... *Taeniorhynchus*

Larvae

1. Eighth segment without a dorsal siphon or respiratory tube ..... *Anopheles*
   Eighth segment provided with a distinctly elongated dorsal siphon or respiratory tube 2
2. Anal segment without a ventral brush ..... *Wyeomyia*
   Anal segment with a ventral brush 3
3. Air-tube without pecten ..... *Taeniorhynchus*
   Air-tube with pecten 4
4. Air-tube with several pairs of ventral tufts ..... *Culex*
   Air-tube with a single pair of ventral tufts 5
5. Head elongate elliptical ..... *Uranotaenia*
   Head nearly circular or transverse 6
6. Air-tube with the tufts close to the base ..... *Theobaldia*
   Air-tube with the tufts near the middle or beyond ..... *Aedes*

Key to the Species of Anopheles

Adults

1. Wings with yellowish-white spots along the costal margin ..... *punctipennis*
   Wings without such markings 2
2. A bronzy or coppery spot at apex of wing ..... *maculipennis*
   Apex of wing uniformly dark colored 3
3. Segments of palpi white scaled at apices ..... *walkeri*
   Segments of palpi uniformly dark scaled ..... *quadrimaculatus*

Larvae

1. Abdomen with six pairs of dorsal palmate tufts 2
   Abdomen with five pairs of dorsal palmate tufts 3
2. Mandibles with 11 terminal teeth; 6 branched hairs on mandible, arranged in an outward projecting row ..... *quadrimaculatus*
   Mandibles with 9 terminal teeth; 10 branched hairs on mandible, arranged in a forward projecting row ..... *walkeri*
3. Lateral plate of the eighth abdominal segment with 22 to 29 (8 to 9 long) teeth ..... *maculipennis*
   Lateral plates of the eighth abdominal segment with 17 to 22 (usually 6 to 7 long) teeth ..... *punctipennis*

Male Hypopygium

1. Processes of ninth tergite long, sharply pointed; dorsal lobe of claspette with two stout, blunt spines, fused at the base ..... *walkeri*
   Processes of ninth tergite short or long, blunt or expanded at tip, dorsal lobe of claspette not as in 1 2

2. Dorsal lobe of claspette with two blunt, stout spines, fused at apex; processes of ninth tergite expanded at apex *quadrimaculatus*
   Dorsal lobe of claspette with free, pointed spines; processes of ninth tergite not expanded at apex 3
3. Dorsal lobe of claspette with three sharply pointed spines; leaflets of mesosome three pairs; processes of ninth tergite very long and bluntly rounded at apex ..... *maculipennis*
   Dorsal lobe of claspette with two sharply pointed spines; leaflets of mesosome four pairs; processes of ninth tergite short, curving outward ..... *punctipennis*

Key to the Species of Aedes

Adults

1. Tarsal joints ringed with white 2
   Tarsal joints not ringed with white 12
2. Tarsi with white rings on both ends of the joints 3
   Tarsi with white rings on basal ends of the joints only 6
3. Wing scales black and white intermingled 4
   Wing scales uniformly dark colored 5
4. Wing scales uniformly mottled, black and white ..... *campestris*
   Vein R4+5 entirely dark scaled ..... *dorsalis*
5. Mesonotum entirely reddish-yellow ..... *canadensis*
   Mesonotum pale with broad, dark, median stripe ..... *atropalpus*
6. Proboscis of female ringed with white ..... *nigromaculis*
   Proboscis of female not ringed with white 7
7. Tarsal white rings very narrow ..... *vexans*
   Tarsal white rings broad especially on the hind legs 8
8. Large yellowish species; abdomen covered with yellowish scales, not banded ..... *flavescens*
   Somewhat smaller species with little yellow; abdomen more or less distinctly banded 9
9. Lower mesepimeral bristles absent 10
   Lower mesepimeral bristles present 11
10. Mesonotum reddish-brown medianly, whitish or yellowish white on the sides ..... *excrucians*
    Mesonotum entirely reddish-brown ..... *riparius*
11. Lower mesepimeral bristles only two ..... *fitchii*
    Lower mesepimeral bristles three to five ..... *stimulans*
12. Lower mesepimeral bristles absent 13
    Lower mesepimeral bristles present 17
13. Mesonotum dark brown centrally, silvery on the sides ..... *triseriatus*
    Mesonotum not so marked 14
14. Wing scales bicolored, black and white intermingled ..... *spencerii*
    Wing scales uniformly dark scaled 15
15. Abdomen with continuous, or nearly so, lateral white line ..... *cinereus*
    Abdomen with white spots, never a continuous lateral line 16

16. Mesonotum with narrow, dark brown, median line and two broad, brassy stripes, sides dark brown to black ..... *trivittatus*
Mesonotum with broad, dark brown, median stripe and two narrow, lateral antescutellar yellowish stripes; sides yellow or golden yellow ..... *aurifer*
Mesonotum with golden-brown median stripe; sides yellowish-white to white ..... *hirsuteron*
17. Lower mesepimeral bristles only one, rarely two, small ..... *intrudens*
Lower mesepimeral bristles three or more, stout 18
18. Mesonotum with paired brown median lines 19
Mesonotum with a single median brown line or stripe 20
19. Paired median lines separated by a narrow yellow line; sides grayish ..... *communis*
Paired median line separated by a golden brown line; sides white ..... *impiger*
Mesonotum yellow, lines slender, often conjoined into a median stripe; legs very deep black ..... *diantaeus*
20. Mesonotum with dark brown median stripe; sides golden to reddish brown ..... *punctor*
Median stripe very broad, the mesonotum often entirely grayish; sides gray to whitish ..... *trichurus*

Male Hypopygium

1. Claspers inserted before apex of side-piece, furcate at base ..... *cinereus*
Claspers not inserted before apex of side-piece, not furcate at base 2
2. Clasper furcate at apex. Claspette lacking a filament, ending in a setiferous knob ..... *vexans*
Clasper not furcate at apex. Claspette with a filament 3
3. Side-piece without a distinct apical lobe 4
Side-piece with both apical and basal lobes 6
4. Side-piece with a small group of long setae on the inner margin at or beyond the middle ..... *triseriatus*
Side-piece without such a group of setae 5
5. Filament of claspette much shorter than the stem ..... *atropalpus*
Filament of claspette as long as or longer than the stem ..... *nigromaculis*
6. Apical lobe a flattened setiferous area ..... *canadensis*
Apical lobe not as above 7
7. Basal lobe a flattened setiferous area reaching almost to the apical lobe. Spines absent ..... *excrucians*
Basal lobe not as above 8
8. Side-piece with a dense hair tuft either distad of the apical lobe or along the basal margin of the apical lobe 9
Side-piece not as described above 11

9. Side-piece with a dense tuft of hairs along the basal margin of the apical lobe; filament of claspette greatly expanded and ending in a recurved hook-like tooth ..... *diantaeus*
Side-piece with a dense tuft of hairs beyond the apical lobe; filament of claspette not as above 10
10. Filament of claspette with a large median retrorse hook; basal lobe nearly cylindrical and bears at its apex a single stout spine ..... *aurifer*
Filament of claspette with a slight median tooth; basal lobe cylindrical and bears two stout apical spines and another spine at the base ..... *intrudens*
11. Apical lobe with short retrorse clinging setae 12
Apical lobe without short retrorse clinging setae; either nearly bare or with long hairs 14
12. Filament of claspette shorter than the stem 13
Filament of claspette as long as or longer than the stem ..... *hirsuteron*
13. Basal lobe semi-detached, the apical portion expanded, clothed with numerous short setae; spine stout and associated with a row of slender hairs ..... *spencerii*
Basal lobe large, quadrangular, extending nearly to the apical lobe; spine slender, with a group of long hairs closely associated with it ..... *punctor*
14. Basal lobe uniformly long haired; no large, distinct spine ..... *trichurus*
Basal lobe with one or more stout spines 15
15. Filament of claspette with long median retrorse non-serrated spine ..... *trivittatus*
Filament of claspette without retrorse median spine 16
16. Basal lobe with a single stout spine on the margin 17
Basal lobe with two short spines on the outer margin ..... *dorsalis*
Basal lobe with several long hairs on the margin, all nearly the same length, one a little stouter ..... *campestris*
17. Apical lobe with few or no short setae on its dorsal face ..... *impiger*
Apical lobe with numerous long or short setae on its dorsal face 18
18. Filament of claspette shorter than the stem 19
Filament of claspette as long as or longer than the stem 20
19. Filament of claspette sharply angulate at the base ..... *fitchii*
Filament of claspette not sharply angulate at the base ..... *communis*
20. Filament of claspette strongly angulate at middle; basal lobe long and narrow, reaching to apical lobe ..... *flavescens*
Filament of claspette not angulate at middle; basal lobe not as described above 21
21. Basal lobe broadly quadrangular; filament of claspette as long as the stem ..... *stimulans*
Basal lobe conical; filament of claspette longer than the stem ..... *riparius*

LARVAE

1. Air-tube with hair tuft within the pecten 2
   Air-tube with hair tuft beyond the pecten 3
2. Air-tube with several dorsal hair tufts ..... *trichurus*
   Air-tube without dorsal hair tufts ..... *atropalpus*
3. Pecten with detached teeth outwardly 4
   Pecten without detached teeth outwardly 12
4. Anal segment ringed by the dorsal plate ..... *nigromaculis*
   Anal segment not ringed by the dorsal plate 5
5. Air-tube at least three and one-half times as long as wide 6
   Air-tube three times as long as wide or less 7
6. Both pairs of dorsal head hairs multiple ..... *cinereus*
   Both pairs of dorsal head hairs double ..... *excrucians*
7. Antenna large, enlarged basally; tuft beyond the middle ..... *aurifer*
   Antenna not enlarged basally; tuft before the middle 8
8. Antenna as long as the head ..... *diantaeus*
   Antenna not as long as the head 9
9. Upper and lower head hairs single ..... *spencerii*
   Upper and lower head hairs double ..... *riparius*
   Upper and lower head hairs not both double 10
10. Upper and lower head hairs multiple, lateral abdominal hairs single beyond the second segment ..... *intrudens*
    Upper head hairs multiple, lower double; lateral abdominal hairs not single beyond the second segment 11
11. All lateral abdominal hairs double ..... *flavescens*
    Lateral abdominal hairs on the first and second segments multiple, third to fifth double ..... *vexans*
12. Comb scales few in a single or irregularly single row ..... *triseriatus*
    Comb scales more numerous, arranged in a triangular patch 13
13. Anal segment ringed by the dorsal plate 14
    Anal segment not ringed by the dorsal plate 15
14. Upper and lower head hairs double ..... *punctor*
    Upper and lower head hairs single ..... *trivittatus*
15. Air-tube at least four times as long as wide ..... *fitchii*
    Air-tube never four times as long as wide, usually three times or less 16
16. Both pairs of dorsal head hairs single 17
    Both pairs of dorsal head hairs never single 19
17. Anal gills budlike, much shorter than anal segment ..... *dorsalis*
    Anal gills as long as or slightly longer than anal segment 18
18. Single scale of comb with a broad apex bearing four to seven stout spines all about same size and length ..... *communis*
    Single scale of comb with a pointed apex bearing a single stout spine and numerous shorter lateral spines ..... *impiger*
19. Both pairs of dorsal head hairs multiple ..... *canadensis*
    Both pairs of dorsal head hairs not multiple 20

20. Lower head hairs single, upper multiple ..... *campestris*
Lower head hairs double, upper three or more ..... *hirsuteron*
Lower head hairs single, upper double ..... *stimulans*

Keys to the Species of Culex

Adults

1. Proboscis ringed with white scales ..... *tarsalis*
Proboscis not ringed with white 2
2. Abdominal segments transversely white banded apically ..... *apicalis*
Abdominal segments with basal white bands or none 3
3. Abdominal segments without basal white bands ..... *salinarius*
Abdominal segments with basal white bands 4
4. Basal white band of the second abdominal segment usually not triangularly produced medianly ..... *territans*
Basal white band of the second abdominal segment usually triangularly produced medianly ..... *pipiens*

Male Hypopygium

1. Lateral plates of the mesosome without processes, united before the apex by a narrow chitinous bridge ..... *apicalis*
Lateral plates of the mesosome with processes 2
2. Apical lobe with at least eight appendages ..... *pipiens*
Apical lobe with five or six appendages 3
3. Mesosome without median or lateral processes, consisting of two recurved plates ..... *territans*
Mesosome with median and lateral processes 4
4. Tenth sternites heavily chitinized, each terminating in a large, rounded knob, crowned with blunt and pointed spines ..... *tarsalis*
Tenth sternites slightly chitinized, sharply pointed, and bearing only pointed spines ..... *salinarius*

Larvae

1. Antenna with the tuft at or before the middle; air-tube with a pair of tufts far beyond the pecten and scattered single hairs ..... *territans*
Antenna with the tuft well beyond the middle; air-tube with several tufts 2
2. Both pairs of head hairs long and single ..... *apicalis*
Both upper and lower head hairs multiple 3
3. Air-tube long and slender, 7 x 1, slightly expanded before the apex ..... *salinarius*
Air-tube not over 5 x 1, uniformly tapering toward the apex 4
4. Air-tube with five pairs of tufts, none displaced or out of line ..... *tarsalis*
Air-tube usually with only four pairs of tufts, next to the last tuft more dorsal and out of line ..... *pipiens*

Keys to the Species of Theobaldia

1. Tarsi with faint whitish rings at both ends of the joints..... *morsitans*
   Tarsi without white rings..... 2
2. Scales of wings mixed, black or brown and white, especially along the costal margin..... *inornata*
   Scales of wings all black or brown, no white scales..... *impatiens*

MALE HYPOPYGIUM

1. Apical lobe present..... *impatiens*
   Apical lobe absent..... 2
2. Lobes of the ninth tergite with short, broad spines..... *inornata*
   Lobes of the ninth tergite with rather long slender setae..... *morsitans*

LARVAE

1. Pecten of the air-tube produced into long hairs on the outer half 2
   Pecten not produced into long hairs on the outer half..... *morsitans*
2. Both pairs of head hairs multiple (6), and of about equal length..... *impatiens*
   Lower head hairs of three or four long hairs; upper multiple and shorter than the lower head hairs..... *inornata*

DESCRIPTION OF SPECIES

Aedes atropalpus Coquillett

1902 *Culex atropalpus* Coquillett, Can. Ent. 34:292.

Recognition Characters: ADULTS.—Mesonotum with a broad, dark-brown, median line; golden-yellow around the sides. Tarsi with white rings on both ends of the joints. A very small species.

Dyar (1928) recognizes two races of this species: *atropalpus atropalpus* from the Atlantic States, in which the light markings of the mesonotum are golden yellow, and *atropalpus epactius* from Arizona and Mexico, in which the light coloration of the mesonotum is white. The Minnesota individuals have the coloration of the eastern race.

MALE HYPOPYGIUM.—Apical lobe of side-piece absent. Claspettes rather long, with a subapical seta and a basal seta on each stem; filament of claspettes shorter than the stem. The hypopygium might be confused with *Aedes triseriatus* Say, but these may easily be separated by the presence of a group of long setae on the inner margin near the middle of the side-piece of the latter.

LARVAE.—Air-tube short; pecten extending nearly to the tip and enclosing a hair tuft within the last few teeth. The larvae have the same specific gravity as water and float with ease at any depth; this provides an excellent field characteristic for use in identification.

Life Cycle: The winter is passed in the egg stage; the larvae appear in the spring as early at May 6 and are to be found at all times

during the summer. The latest record of larvae in Minnesota is August 11. Dyar (1904) has shown that there may be several generations each season in the eastern states, while the data at hand suggest that this is also true in Minnesota.

Larval Habitat: The larvae of this species have been found only in small potholes along rapids in rivers and, on one occasion, they were taken from rock pools along the shore of Lake Superior. Dyar (1904) states that the egg masses deposited in the late fall are glued to the sides of the pools at water level and the females, which emerge in the spring, scatter the eggs loosely over the surface of the water. This habit of attaching the eggs to the rocks is insurance against having them washed away by the spring floods. The larvae taken were not in association with any other species.

Importance: The adults of *Aedes atropalpus* Coquillett have been observed to feed freely when encountered, but, since their distribution is limited and the numbers are few, this species is not a serious pest. The adults were never observed to have migrated away from their breeding places.

Distribution: This very delicate and interesting species has been taken only in the northeastern part of the state. Examination of the potholes in a small stream in Alexander Ramsey State Park on July 30, 1933, failed to reveal its presence. Insofar as the writer can determine, the finding of this race of *Aedes atropalpus* Coquillett in Minnesota extends its known range far to the west of all previous records. Minnesota records are: *Larvae*[3]—Jay Cook State Park, May 6, 1934, June 25, 1933 and 1934, July 18, 1932, August 11, 1933; Knife River (Lake Superior), July 10, 1934; Sucker River, July 1, 1935.

Aedes aurifer Coquillett

1903 *Culex aurifer* Coquillett, Can. Ent. 35:255.

Recognition Characters: ADULTS.—Occiput black with a median line of yellowish scales and a black patch on each side; the sides light yellow. Mesonotum golden yellow with a median line of bronzy-brown scales widening posteriorly. Abdomen dark with triangular, lateral, white spots. Legs black.

MALE HYPOPYGIUM.—The small tuft of hair beyond the apical lobe on the side-piece and the large, median retrorse hook on the filament of the claspette are sufficient to separate *Aedes aurifer* Coquillett from the other Minnesota species.

LARVAE.—Antenna longer than head, tuft beyond the middle. Upper and lower head hairs double. Lateral comb of eighth segment consisting of about 25 scales arranged in a triangular patch. Air-tube three times as long as wide; pecten extends to the middle with a tuft beyond.

[3] The records listed as *Larvae* for each species represent collections of larvae, some or all of which were reared through to the adult stage.

Life Cycle: This species spends the winter in the egg stage and there is only a single generation each season (Dyar 1904). The three records of larvae taken were on May 9, placing it among the early species. The adults persist until mid-July, the latest record being July 17.

Larval Habitat: The larvae are reported by Dyar (1904) as being commonly associated with cranberry bogs. In the present study the larvae were in one instance taken from a cranberry bog, while the other two records are from roadside pools derived from melting snow. The larvae were found associated with *Aedes vexans* Meigen, *Aedes cinereus* Meigen, *Aedes fitchii* F. and Y., *Aedes canadensis* Theo., *Aedes excrucians* Walker, *Aedes punctor* Kirby, *Aedes impiger* Walker, and *Aedes stimulans* Walker.

Importance: Although the adults feed freely during the day and evening, its rarity in Minnesota places it among the unimportant species.

Distribution: *Aedes aurifer* Coquillett is probably limited in distribution to the wooded sections of the state (Fig. 8).

Aedes campestris Dyar and Knab

1907 *Aedes campestris* Dyar and Knab, Jour. N. Y. Ent. Soc. 15:213.

Recognition Characters: ADULTS.—Mesonotum yellowish-scaled with an undivided, broad, brown, median stripe. Wing scales uniformly bicolored with the pale scales predominating. Tarsi with rings on both ends of the joints. This species may easily be confused with *Aedes dorsalis* Meigen from which it can be separated by its lighter coloration, larger size, and vein R4+5 which, in the latter, is all black.

MALE HYPOPYGIUM.—Apical lobe small, rounded, and covered with long setae. Basal lobe with a single, large spine on the outer margin at the base, several smaller spines around it, and densely covered with setae. Claspette with filament slightly expanded in middle; stem with several subapical setae.

LARVAE.—Lower head hairs single, upper double. Air-tube twice as long as wide, the pecten reaching out three-fourths of the length of the tube, with small tuft located near the tip. Anal segment ringed by the dorsal plate. Anal gills longer than the segment.

Life Cycle: The winter is passed in the egg stage and larvae have been found as early as April 25 and as late as July 19. The adults persist throughout most of the summer, the latest record being August 15. Mail (1930) has shown that the eggs of this species can survive storage at a temperature slightly above freezing for a period of 20 months.

Larval Habitats: During the course of this investigation, the larvae have been collected but a few times. They probably occur more often in temporary rain pools, but, on one occasion, were taken in a marshy habitat. The larvae were found in association with *Aedes dorsalis* Meigen, *Aedes nigromaculis* Ludlow, *Aedes vexans* Meigen, and *Culex tarsalis* Coq.

Importance: This species is apparently not abundant in Minnesota and should not be classified as an important pest. The adults feed at all hours.

Distribution: (Fig. 7) This is a plains species and is, therefore, more abundant in the western half of the state.

Aedes canadensis Theobald

1901 *Culex canadensis* Theobald, Mon. Culic. 2:3.

Recognition Characters: ADULTS.—A small mosquito with reddish-brown mesonotum, tarsi with rings on both ends of joints; and wing scales all dark.

MALE HYPOPYGIUM.—Apical lobe flattened, covered with short setae. Filament of claspette slender, pointed, and almost as long as the stem. Basal lobe large, covered with fine setae.

LARVAE.—Upper and lower head hairs multiple. Lateral abdominal hairs double on the first to fifth segments, single on the sixth. Comb scales of eighth segment in an irregular patch. Air-tube three times as long as wide; pecten extending one-third of the length of the air-tube; tuft located beyond pecten.

Life Cycle: This species overwinters in the egg stage, hatching in the early spring, the first record of larvae being on April 19. Larvae have been taken as late as July 6. Adults are common from early May, through the month of June, and have been found as late as July 17.

Larval Habitats: Larvae are commonly found in shaded pools in a coniferous forest and also in temporary rain pools in a more open country. They were taken less often in shaded pools in the hardwood section of the state. The larvae of *Aedes canadensis* Theobald are associated with *Aedes cinereus* Meigen, *Aedes punctor* Kirby, *Aedes excrucians* Walker, *Aedes communis* DeGeer, *Theobaldia inornata* Williston, and *Theobaldia morsitans* Theobald.

Importance: This is an abundant species over the northern half of the state, and, although it is quite annoying as a pest, it should not be ranked with *Aedes communis* DeGeer. The adults feed during the day and also in the evening when their haunts are invaded.

Distribution: (Fig. 5) This species is found in all the timbered regions of the state.

Aedes cinereus Meigen

1818 *Aedes cinereus* Meigen, Syst. Beschr. Eur. Zweifl. Ins. 1:13.

Recognition Characters: ADULTS.—This small, dark mosquito may be recognized by the reddish-brown mesonotum, black legs, absence of lower mesepimeral bristles, and basal, segmental, white bands of abdomen which converge laterally to make a white line.

MALE HYPOPYGIUM.—The origin of the claspers before the apex of the side-pieces is sufficient to identify the hypopygium of this species.

LARVAE.—Small, about 6 mm. in length. Anal segment not ringed by the dorsal plate. Air-tube long, slender, about three and one-half

times as long as wide. Upper and lower head hairs multiple. Lateral abdominal hairs double on first and second segments, single on third to sixth segments. Lateral comb scales of eighth segment arranged in an imperfect double row.

Life Cycle: The winter is passed in the egg stage and there is apparently but a single generation each season. The larvae have been taken in Minnesota from April 19 to July 17. Adults also appear early and persist throughout the season, the latest record being August 23.

Larval Habitats: The larvae of this species have been taken in a variety of habitats, most frequently occurring in pools in the coniferous forests, woodland pools in the hardwood region, temporary rain pools which are unshaded, open bogs, and marshes. Associated with *Aedes canadensis* Theobald, *Aedes punctor* Kirby, *Aedes excrucians* Walker, *Theobaldia inornata* Williston, *Aedes vexans* Meigen, *Aedes fitchii* F. & Y., *Aedes communis* DeGeer, and *Aedes impiger* Walker.

Importance: The adults are commonly encountered in wooded regions where they feed at any time. Although not particularly abundant in numbers, this species is of considerable importance in Minnesota.

Distribution: (Fig. 5) This species commonly occurs in both the hardwood and coniferous forest regions of the state.

Aedes communis DeGeer

1776 *Culex communis* DeGeer, Mem. des Ins. 6:316.

Recognition Characters: ADULTS.—Occiput grayish-yellow. Mesonotum dull yellow, two dark lines reaching back two-thirds and posterior half lines. Median lines separated by a row of pale scales. Legs black. Abdomen with basal segmental white bands; venter largely grayish-white. The coloration of the mesonotum is sometimes variable, the median lines being indistinct or not separated by pale scales.

MALE HYPOPYGIUM.—Apical lobes prominent, clothed with long setae on the dorsal face. Filament of claspette shorter than the stem. Basal lobe somewhat detached at base; margin with a row of prominent recurved spines; a single stout spine arises near the base.

LARVAE.—Upper and lower head hairs single. Lateral abdominal hairs double on first to fifth segments, single on sixth. Anal segment not ringed by the dorsal plate. Anal gills longer than anal segment and pointed. Pecten without detached teeth outwardly. Tuft of antenna large, situated before the middle. Comb scales of eighth segment about 45, arranged in a triangular patch.

Life Cycle: This species passes the winter in the egg stage and has but one generation each year. It is one of the early spring species; the larvae are found during the month of May and early June, the earliest record being May 5. The peak of emergence as adults usually occurs between May 20 and 25. The adults may persist until late in the season, the latest record for Minnesota being August 7. Shortly after emergence the males swarm. This behavior was observed at Itasca

State Park on May 28, 1936, just after sunset, where a small swarm of males of this species was observed hovering by a water tower at an elevation of about 50 feet.

Larval Habitats: The larvae are found almost exclusively in temporary pools in coniferous forests where they are associated with *Aedes punctor* Kirby, *Aedes cinereus* Meigen, *Aedes canadensis* Theo., *Aedes diantaeus* H., D., and K., and *Aedes impiger* Walker.

Importance: *Aedes communis* DeGeer is one of the most abundant and annoying species wherever it occurs. The bite is exceedingly painful and it feeds readily at all hours when its haunts are invaded. The great swarms of mosquitoes met with in the northern forests during late May and early June more often belong to this species.

Distribution: (Fig. 4) This species is widely distributed in the forested region throughout the northern half of the state.

Aedes diantaeus Howard, Dyar, and Knab

1917 *Aedes diantaeus* Howard, Dyar, and Knab, Mosq. of N. and Cent. America and W. I., 4:758.

Recognition Characters: ADULTS.—Proboscis long, black. Occiput with yellowish scales. Mesonotum yellowish with two broad, dark, median lines; median lines may be fused. Abdomen with very narrow, basal, segmental, white bands widening laterally into white spots; venter grayish-white with apical, segmental, dark scales usually present. Legs long and black with bluish reflections. Slight variations in color make it difficult to separate this species from *Aedes punctor* Kirby at times; however, the typical markings of both are quite different.

MALE HYPOPYGIUM.—The hypopygium of this species is one of the easiest to recognize of the Minnesota *Aedes*. The great mass of hairs along the basal margin of the apical lobe and the filament of the claspette with its triangular expansion terminating in a recurved hook are sufficiently diagnostic.

LARVAE.—Antenna longer than the head, slender, not expanded, and with a hair tuft at the middle. Upper head hairs three, lower usually four or five. Lateral abdominal hairs triple on the first two segments, double on the third to fifth, and single on the sixth. Anal gills short.

Life Cycle: There is but a single generation each year. The larvae appear in late May and are to be found until as late as July 3. The latest record of adults being taken was on July 12, although they doubtless persist until a later date. The males of *Aedes diantaeus* H., D., and K., as pointed out by Dyar (1922), do not swarm, but pursue the females singly when they are abundant. Mating was observed at the same locality on the Cloquet Forest Experiment Station tract two consecutive years, the dates being June 26, 1933, and June 27, 1934. The observations in June 1933 were made at 10:00 a.m. in a shaded spruce swamp with an air temperature of 65° F. The following season, the observations were made at 2:00 p.m. at the same location with the air

temperature at 69° F. The behavior of the males was the same at both observations. They pursued the females as they were attempting to feed; engagement took place in the air, the two remaining united for only a few seconds. In one instance, only, did a female alight on the writer while united with the male.

Larval Habitat: The larvae have been found almost exclusively in cold, shaded pools in the coniferous forest. They are found in association with *Aedes punctor* Kirby, *Aedes communis* DeGeer, *Aedes cinereus* Meigen, *Aedes canadensis* Theo., and *Aedes vexans* Meigen.

Importance: Although *Aedes diantaeus* H., D., and K. feeds readily at all hours when encountered, owing to its spotted distribution and confinement to the denser swamps, it is not a major pest.

Distribution: (Fig. 4) This species is confined to the dense swamps of the coniferous forest.

Aedes dorsalis Meigen

1830 *Culex dorsalis* Meigen, Syst. Besch. Eur. Zweifl. Ins. 6:242.

Recognition Characters: ADULTS.—Mesonotum pale yellow with a narrow, median, brown stripe. The dark scales of vein R4+5 separate it from *Aedes campestris* Dyar and Knab. There are definite variations in the shape of the median mesonotal stripe, ranging from a narrow line to a broad one and sometimes double lines, as Mail (1934) has emphasized. The Minnesota specimens examined all had a single, median line.

MALE HYPOPYGIUM.—Apical lobes short, rounded, with rather long setae. Basal lobe constricted at base and expanded apically with two rather stout spines on the margin. Filament of claspette slightly shorter than the stem, expanded in the middle, and ending in a recurved point.

LARVAE.—Upper and lower head hairs single. Anal gills budlike, shorter than the segment. Lateral hairs triple on the first and second segments, and double on the third to sixth segments.

Life Cycle: The winter is passed in the egg stage and the larvae appear quite early in the spring, the earliest record being April 29. Mail (1934) has shown that there may be several generations each summer. The record of larvae on July 19 is probably not the latest that can be obtained in the state. The latest record of appearance of adults is July 27, yet they are doubtless to be found in certain localities in the plains region until late summer.

Larval Habitat: The few records of larvae were all taken from temporary, exposed pools, with one record from very foul, stagnant water. The information relative to larval habitats of this species in Minnesota is quite incomplete. The larvae have been taken in association with *Aedes campestris* Dyar and Knab, *Aedes vexans* Meigen, *Aedes nigromaculis* Ludlow, *Culex tarsalis* Coq., and *Aedes cinereus* Meigen.

Importance: A species which feeds on man and animals freely during the day and also in the evening. It has not been encountered in

large numbers in Minnesota and is a minor pest of man and livestock. The recent demonstration by Knowlton (1935), showing that *Aedes dorsalis* Meigen is a vector of equine encephalomyelitis, places this species in an entirely different category from most of the other aedine species.

Distribution: (Fig. 7) Prairie region extending eastward into the hardwood section. It is doubtless more uniformly distributed in the plains section than the collection records indicate.

Aedes excrucians Walker

1856 *Culex excrucians* Walker, Ins. Saund. Dipt., 429.

Recognition Characters: ADULTS.—This is a large mosquito with wing scales mottled black and white, especially along the costal margin. Occiput with pale yellow scales and a dark patch on either side. Mesonotum usually with a broad, irregular, median stripe of brown scales with the sides lighter; the coloration is somewhat variable.

MALE HYPOPYGIUM.—Apical lobe prominent, clothed with short, curved setae. Basal lobe flattened, usually seen only as a broad patch of setae reaching almost to apical lobe. Filament of claspette shorter than the stem with an angular projection near the middle.

LARVAE.—Air-tube slender and approximately four times as long as wide. Lateral abdominal hairs double on the first and second segments, and single on the third to sixth segments. Anal gills rather pointed and about as long as the segment.

Life Cycle: There is apparently but a single generation each season, the winter being spent in the egg stage and the larvae appearing relatively early in the spring. Larvae have been collected from April 13 to June 19. The adults persist until late summer, the latest record being August 11.

Larval Habitats: The larvae are commonly found in woodland pools, temporary roadside and pasture pools, and cold, shaded pools in the coniferous forest. They are found in association with *Aedes cinereus* Meigen, *Aedes canadensis* Theobald, *Aedes fitchii* Felt and Young, *Aedes punctor* Kirby, *Theobaldia inornata* Williston, *Aedes vexans* Meigen, and *Aedes stimulans* Walker.

Importance: A very annoying species which feeds in the shade at all times when encountered. The only reason that this is not one of the worst mosquito pests in Minnesota is due to the scarcity in numbers present at one time.

Distribution: (Fig. 6) Timbered regions of the state in both the hardwood and coniferous forests.

Aedes fitchii Felt and Young

1904 *Culex fitchii* Felt and Young, Science, N. S. 20:312.

Recognition Characters: ADULTS.—Occiput yellowish-white with a dark patch on each side. Mesonotum dark brown with a broad median

line of light-brown scales, or mottled with no distinct pattern, the coloration variable. Wing scales evenly black and white intermingled. Abdomen with broad, white basal bands; venter largely pale scaled. Tarsi with broad bands at base, especially on hind legs.

MALE HYPOPYGIUM.—Apical lobe large with many long, stout setae. Basal lobe somewhat triangular, covered with short setae; a single, stout spine at the margin. Filament of claspette shorter than the stem, sickle-shaped, expanded at base to form a notch.

LARVAE.—Upper and lower head hairs multiple. Lateral hairs on the first to sixth abdominal segments usually double. Air-tube more than four times as long as wide; pecten not reaching beyond the middle hair tuft near middle of tube.

Life Cycle: The winter is passed in the egg stage and the larvae appear about the first of May. They are to be taken during the month of May, the latest record being June 1. The adults persist through the early summer. The swarming behavior of the males has been described by Knab (1908).

Larval Habitat: The larvae are to be found in a rather wide range of habitats, as along the margins of semipermanent ponds, temporary open pools, woodland pools, and occasionally in open bogs. They are apparently not to be found in shaded pools in the coniferous forest and have been found in association with *Aedes cinereus* Meigen, *Aedes canadensis* Theobald, *Aedes excrucians* Walker, *Aedes stimulans* Walker, *Aedes vexans* Meigen, and *Aedes punctor* Kirby.

Importance: This species bites freely during the daytime in the shade and also at dusk. Although annoying, it is not a major pest.

Distribution: (Fig. 6) Timbered regions of the state in both hardwood and coniferous forests.

Aedes flavescens Müller

1764 *Culex flavescens* Müller, Fauna Ins. Fried. 87.

Recognition Characters: ADULTS.—This large, yellowish species can be identified readily by the dull-yellow, unbanded abdomen. The mesonotum is yellowish-brown and usually has a broad, median stripe of darker scales.

MALE HYPOPYGIUM.—Apical lobe of side-piece large, rounded; some of the setae stout and retrorse. Basal lobe elongate covered with short setae; a stout spine at the outer proximal end. Filament of claspette curved, bladelike, and expanded in the middle.

LARVAE.—Upper head hairs usually four, lower three. Head bulging at the side, wider than long. Ventral brush of anal segment very large with small tufts preceding it proximally.

Life Cycle: There is but a single generation annually and the winter is passed in the egg stage. The larvae are among the first to appear in the spring, the earliest record being April 13. The larvae are common during the month of May, and the latest record for Min-

nesota is May 25. The adults survive until late in the season, according to Matheson (1929). The latest record of adults from Minnesota is July 24, 1921, as reported by Dyar (1923). The males of this species do not swarm as observed by Wesenberg-Lund (1920).

Larval Habitats: The larval records show that this species has been taken from marshy habitats and temporary pools in exposed places. The larvae are commonly found associated with *Theobaldia inornata* Williston, *Aedes excrucians* Walker, *Aedes cinereus* Meigen, *Aedes vexans* Meigen, and *Culex territans* Walker.

Importance: *Aedes flavescens* Müller is not commonly encountered in the adult stage and, for this reason, is negligible as a pest in Minnesota.

Distribution: (Fig. 7) *Aedes flavescens* Müller is found in the wooded regions, exclusive of the coniferous forests, and, in some instances, in prairie country.

Aedes hirsuteron Theobald

1901 *Culex hirsuteron* Theobald, Mon. Culic. 2:98.

Recognition Characters: ADULTS.—Occiput with pale yellow scales; cheeks grayish-white with a patch of black scales. Mesonotum yellowish-gray with a broad, median, dark-brown band, and sublateral stripes posteriorly. Abdomen with basal white bands widening at the sides; venter largely pale scaled.

There may be considerable variation in the size of the adults taken from different localities. The individuals of a large series taken at McGregor, June 19, 1933, were all small in contrast to those taken in other localities. The finding of these size differences led Dyar (1919) to describe the smaller forms as *Aedes vinnipegensis*. The same author (1923) suggests that *vinnipegensis* may be considered a race of *hirsuteron*.

MALE HYPOPYGIUM.—Apical lobe large, round at the apex, and covered with short, clinging setae. Basal lobe prominent, broad at base, conical; a large thickened spine at base surrounded by a tuft of long hair, Matheson (1929).

LARVAE.—Lateral abdominal hairs double on the first to fifth segments and single on the sixth. Dorsal plate of anal segment reaching almost to the mid-ventral line.

Life Cycle: There is probably a single generation each year. The eggs, which are often laid in flood pools, hatch at intervals during the spring when they are covered with water. Dyar (1928) has suggested that the eggs may survive several seasons before hatching if not flooded. The adults may be encountered rather late in the season in some localities. The latest record of adults in Minnesota is July 7.

Importance: This species bites freely in the shade when encountered during the day and also feeds at dusk. The distribution is spotted and only under very local conditions does it prove to be a pest.

Larval Habitat: The information on larval habitats in Minnesota is very incomplete. The larvae have been taken only on two occasions. One batch was from a shaded forest pool, while the other was from a temporary rain pool. The adults were found in large numbers on two localities where it was apparent that the larvae had developed in flood-water pools. This species was found in association with *Aedes canadensis* Theobald, *Aedes cinereus* Meigen, *Aedes punctor* Kirby, *Aedes stimulans* Walker, and *Theobaldia morsitans* Theobald.

Distribution: (Fig. 6) This species is more common in the timbered regions of the state and has been taken in the plains sections.

Aedes impiger Walker

1848 *Culex impiger* Walker, List. Dip. Brit. Mus. 1:6.

Recognition Characters: ADULTS.—This small mosquito is easily recognized by the black legs; mesonotum with paired, median, dark lines, whitish on the sides; and the broad, white bands on the abdomen. The occiput is covered with white scales and has a dark patch on each side.

MALE HYPOPYGIUM.—The hypopygium is unique in having very long, slender, apical lobes. The basal lobes are rounded with a heavy spine and several large setae on the face. Filament of claspette has a distinct, toothlike projection at its base.

LARVAE.—Head wider than long. Antenna with a tuft in the middle. Head hairs single. Air-tube two and one-half times as long as wide. Anal gills short, scarcely longer than the segment.

Life Cycle: There is a single generation annually and the larvae are among the first to appear in the spring. The earliest record of larvae being taken is April 13 and the latest collection is May 28. The latest record of adults is June 24.

Larval Habitats: The larvae have been taken from temporary pools shaded by hardwood timber, cold, shaded pools in the dense coniferous forest, and early, temporary snow pools in the open. This species is more often associated in the larval stage with *Aedes cinereus* Meigen, *Aedes punctor* Kirby, *Aedes communis* DeGeer, and *Aedes canadensis* Theobald.

Importance: *Aedes impiger* Walker feeds freely when it is encountered in the shade during the day as well as in the evening. Apparently there is never a heavy population of the adults except in isolated localities. This is one of the earliest species to emerge in the spring, and, although annoying, it is not a major pest.

Distribution: (Fig. 5) Confined to the wooded region of the northern half of the state, but more common in the northern forest.

Aedes intrudens Dyar

1919 *Aedes intrudens* Dyar, Ins. Ins. Mens. 7:23.

Recognition Characters: ADULTS.—This medium-sized, dull-brown mosquito has a yellowish-brown head and a bronzy-brown mesonotum

often with two narrow, darker, median lines. The abdomen has broad, white basal bands above and is whitish below.

MALE HYPOPYGIUM.—Large tuft of hair on side-pieces beyond apical lobes. Apical lobes prominent, rounded, and covered with long, curved setae. Stem of claspette angular; basal half enlarged with a terminal spine at point where distal half of stem arises. Filament of claspette bladelike, curved, expanded in the middle.

LARVAE.—Air-tube two and one-half times as long as wide; pecten extends to the middle of tube. Lateral abdominal hairs double on the first segment, and single on the second to sixth segments. Upper head hairs usually in fours, lower in threes.

Life Cycle: This species has a single brood each season and the winter is passed in the egg stage. The earliest larvae were taken on May 2 and the latest record is for June 16. Matheson (1929) states that the adults may persist until September. The writer's latest record of adults is July 17.

Larval Habitats: The larvae have been taken from a variety of habitats including woodland pools shaded by deciduous trees, open bogs, marshy localities, and forest pools in dense shade of conifers. The larvae of this species are more frequently associated with *Aedes cinereus* Meigen, *Aedes canadensis* Theobald, *Aedes punctor* Kirby, and *Aedes vexans* Meigen.

Importance: *Aedes intrudens* Dyar feeds at all hours during the day when encountered in the shade and also at dusk. Dyar (1919) has pointed out that at both Banff, Alberta, Canada, and White River, Ontario, Canada, this species persisted in entering houses while the other mosquitoes in that vicinity did not have this habit. On the other hand, Matheson (1929) states that he has never taken it in houses. *Aedes intrudens* Dyar was repeatedly taken in a lake cottage near Carlton during the summer of 1934, and, again in 1935, it was collected in cabins at Itasca State Park. It is by no means the only aedine mosquito in Minnesota which will enter houses, and, according to the experience of the writer, Dr. Dyar overemphasized the fondness of this species for such invasions. It is a very annoying pest and at times is very abundant.

Distribution: (Fig. 5) Wooded regions of the state, being more common in the northern half.

Aedes nigromaculis Ludlow

1907 *Grabhamia nigromaculis* Ludlow, Geo. Wash. Univ. Bull. 5:85.

Recognition Characters: ADULTS.—The white-ringed proboscis is sufficient to separate this species from all the other *Aedes* in Minnesota.

MALE HYPOPYGIUM.—Apical lobe of side-piece absent. Basal lobe flattened, covered with setae. Filament of claspette slender, long as the stem.

LARVAE.—Head hairs single. Anal segment ringed by the plate. Air-tube twice as long as wide; pecten reaching three-fourths of its length, and with three detached outer teeth.

Life Cycle: The winter is passed in the egg stage and, according to Mail (1934), there may be several generations each season. The larvae were taken only on one occasion, this being on July 19. A single male was taken at Brown's Valley on August 4. The seasonal cycle of this species in Minnesota is very incompletely known.

Larval Habitat: Larvae were taken from a foul, stagnant, barnyard pool near Little Falls, where they were in association with *Aedes vexans* Meigen, *Aedes dorsalis* Meigen, *Aedes campestris* Meigen, and *Culex tarsalis* Coquillett.

Importance: This species is said to be a severe pest of man and domestic animals where it is common. The data available indicate that it is rare in Minnesota. The demonstration by Knowlton (1935) that the virus of equine encephalomyelitis can be successfully transmitted from guinea pig to guinea pig by this mosquito should not be disregarded in a consideration of its importance.

Distribution: (Fig. 7) This mosquito is probably limited largely to the plains regions of the state.

Aedes punctor Kirby

1837 *Culex punctor* Kirby, Richardson's Fauna Bor.-Amer. 4:309.

Recognition Characters: ADULTS.—Occiput and cheeks pale yellow. Mesonotum reddish-brown with a darker, broad, median line which is often divided by pale scales. Color of mesonotum variable; sometimes the median band is indistinct. Abdomen with narrow, basal, segmental, white bands; venter grayish-white, the segments with median, apical, dark scales. Legs black; the tips of femora white.

MALE HYPOPYGIUM.—Apical lobe prominent, pointed, with short, clinging setae. Basal lobe large, quadrangular, clothed with short setae; a large spine surrounded by several smaller ones arising on the proximal margin.

LARVAE.—Upper and lower head hairs usually double. Lateral abdominal hairs double on the first and single on the second to seventh segments. Anal segment longer than broad and ringed by the plate. Air-tube about three times as long as wide; pecten even and extending to about middle of the tube.

Life Cycle: The winter is passed in the egg stage and there is apparently a single generation each season. Larvae have been collected from May 7 until July 10. The late records are all from cold, shaded forest pools where the temperature of the water may be as low as 10° C. until mid-July. The low temperature of the water where the larvae are commonly found is a possible explanation for their presence at this late date. The adults have been taken as late as August 11 in the northern swamps.

Larval Habitats: The larvae of this species are more often found in the cold, shaded pools of the coniferous forest. During the early season they have been taken in woodland pools in deciduous forest

regions and, a few times, from open bogs. The larvae are found in association with *Aedes cinereus* Meigen, *Aedes canadensis* Theobald, *Aedes communis* DeGeer, *Aedes diantaeus* H., D., and K., *Aedes excrucians* Walker, *Aedes impiger* Walker, and *Theobaldia morsitans* Theobald.

Importance: *Aedes punctor* Kirby is a painful and persistent biter at all hours in dense swamps. Its abundance during the late spring and early summer makes it one of the most annoying mosquitoes in the state. In most of the swamp lands of northern Minnesota the population of this species reaches a peak during the first two weeks in June, assuming the position relinquished by the waning *communis* at this period. It is perhaps the most serious mosquito pest over a long period of time to be found in northern Minnesota.

Distribution: (Fig. 4) This species is limited in its distribution to the northern half of the state where it is especially abundant in the dense forested regions.

Aedes riparius Dyar and Knab

1907 *Aedes riparius* Dyar and Knab, Jl. N. Y. Ent. Soc. 15:213.

Recognition Characters: ADULTS.—Occiput brown with yellowish scales in the middle; sides light with a brown patch. Mesonotum reddish-brown with no distinct pattern, white scales around the edges. Abdomen usually with basal, segmental, white bands; coloration often variable. Wing scales dark with some admixture of white scales on the costal margin.

MALE HYPOPYGIUM.—Apical lobe prominent, rounded with many recurved setae; basal lobe conical, with numerous, stout setae and a stout, basal spine surrounded by a tuft of long setae. Filament of claspette sickle-shaped, longer than the stem.—Matheson (1929).

LARVAE.—Head hairs in two's. Lateral comb of the eighth segment of seven or eight scales in an irregular row, each with a long central thorn. Air-tube about three times as long as wide, the pecten reaching near the middle, the last two or three teeth detached, followed by a three-haired tuft. Anal gills rather short, pointed.—Dyar (1928).

Life Cycle: The winter is passed in the egg stage and there is, apparently, a single generation each year. Dyar (1923) collected the larvae in large numbers at Winnipeg, Manitoba, about the middle of May, 1922, and reports finding recently emerged adults at Warroad, Minnesota, on May 22, 1922. In the present study, a single specimen was taken at Badger, June 12, 1934.

Larval Habitats: The larvae are said by Dyar (1923) to prefer spring pools in the prairie region, particularly those under scrub oaks and other shrubbery where the forest and prairie meet.

Importance: *Aedes riparius* D. and K., insofar as known, is not an important mosquito in Minnesota.

Distribution: It probably occurs all along the edge of the prairie region of the state. The only Minnesota records: Captured Adult—

Badger, June 12, 1934. Records from Dyar (1923): Warroad, May 22, 1922; Fort Snelling, June 10, 1908; Thief River Falls, May 30, 1922; Barnesville, June 2, 1922; Crookston, June 1, 1922.

Aedes spencerii Theobald

1901 *Culex spencerii* Theobald, Mon. Culic. 2:99.

Recognition Characters: ADULTS.—Mesonotum yellowish-gray with a broad, median stripe of brown scales. Wing scales mixed black and white; those of veins R, R4+5 and Cu_1 and Cu_2 all black. Abdominal segments with broad basal and narrow apical grayish-white bands, a median dorsal stripe of this color; often the dorsum is entirely grayish-white; venter pale-scaled.

The coloration of the abdomen is quite variable; specimens taken from the same locality have shown a variation ranging from those in which the median, pale stripe is absent to a condition in which the whole dorsal surface of the abdomen is grayish-white.

MALE HYPOPYGIUM.—The hypopygium of this species is shown in Figure 2.

LARVAE.—Head rounded; antennae small, tuft near the middle; upper and lower head hairs single. Lateral comb of eighth segment consisting of about ten scales arranged in an irregular, double row. Air-tube about two and one-half times as long as wide; pecten extending to the middle, the last two teeth detached; tuft small, slightly beyond pecten. Anal segment longer than wide, the dorsal plate extending to near the mid-ventral line. Lateral abdominal hairs single from first to sixth segments.

Life Cycle: *Aedes spencerii* Theobald overwinters in the egg stage and the larvae appear quite early in the spring. The earliest record of mature larvae has been April 28. How late in the season larvae are to be found is not evident as there are no records of them being taken after May 10. On the other hand, adults have been collected from May 2 to September 15. There is, apparently, but a single generation each season since no larvae have been taken at a very late date and limited tests show that the eggs do not hatch in the laboratory after alternate wetting and drying. These observations point to an exceedingly long life in the adult stage.

Larval Habitats: The larvae have been taken in early, temporary rain pools and in marshes. They were taken in one instance in association with *Aedes canadensis* Theobald.

Importance: *Aedes spencerii* Theobald is strictly diurnal in its feeding habits and, for this reason, is often annoying in the early season under conditions where one would not expect to be attacked by mosquitoes. It is one of the most abundant and serious pests in prairie regions during the early spring.

Distribution: (Fig. 7) Although a typical plains species, *Aedes spencerii* Theobald is by no means limited to the prairie region. It is

fairly common in the Twin Cities area in the early season and was taken with ease at the Cloquet Forest Experiment Station and at Itasca State Park during the latter part of May, 1936.

Aedes stimulans Walker

1848 *Culex stimulans* Walker, List. Dipt. Brit. Mus. 1:4.

Recognition Characters: ADULTS.—Occiput yellowish-white, usually with a dark patch on each side. Mesonotum brown above with lighter-colored scales on the sides; sometimes mottled with no distinct pattern. Abdomen with broad, segmental, white bands, venter largely whitish-scaled. Wing scales black and white admixed, especially on the costal margin. This species often has the coloration so much like *Aedes excrucians* Walker that the two may be confused. However, the presence of a group of three or four lower mesepimeral bristles in *stimulans* is sufficient to distinguish it from the latter.

MALE HYPOPYGIUM.—Apical lobe long, rounded; inner face with many heavy setae. Basal lobe broad, slightly expanded, with a heavy, marginal spine and covered with smaller setae. Claspette with slender, curved stem and a bladelike filament which may be so expanded in the middle as to have an angular spinelike surface on one side. Side-piece with the ventral inner margin densely clothed with long hairs.

LARVAE.—Head wider than long; antennae with a tuft near the middle. Upper head hairs two or three, lower usually single. Lateral abdominal hairs usually double on the first segment, double on the second to fifth segments, and single on the sixth.

Life Cycle: This species overwinters as eggs and the larvae are among the first to appear in the spring in central Minnesota. The collection records show that larvae may be found from April 10 to May 30, the records of the latter date being from the more northern part of the state. Adults may be found from the first of May until the middle of July. Matheson (1929) states that he has taken adults of this species in mid-September in the region of Ithaca, New York. It is evident that they are very long-lived, persisting in the woods throughout the summer. There is a single generation annually.

Larval Habitats: The larvae are more often found in shaded woodland pools and in temporary rain pools exposed to sunlight. They have been recorded from forest pools and semipermanent pools. They may be found in association with *Aedes fitchii* F. and Y., *Aedes excrucians* Walker, *Aedes cinereus* Meigen, *Aedes canadensis* Theobald, *Culex tarsalis* Coquillett, and *Theobaldia inornata* Williston.

Importance: This species feeds readily in the woods at all hours, the bites being very painful. In abundance, it does not rank with *vexans, communis,* and *punctor,* yet its broad distribution and vicious habit make it one of the most important species in the eastern half of the state. The data obtained at University Farm, St. Paul, show clearly that the adults will migrate more than a mile from the place of emer-

gence. This tendency to move away from its breeding grounds and the habit of entering houses make it a pest in small towns and the suburban districts of cities.

Distribution: (Fig. 6) This species is apparently evenly distributed over the wooded part of the state east of the prairies. Although it is a common species in the zone of coniferous forest, the larvae are not usually found in the dense forest.

Aedes trichurus Dyar

1904 *Culex trichurus* Dyar, Jl. N. Y. Ent. Soc. 12:170.

Recognition Characters: ADULTS.—This is a large, conspicuous mosquito and can be identified easily by the gray coloration as it feeds. Occiput yellowish; sides white. Mesonotum with an irregular, central band of yellowish-brown scales; sides grayish-white. Sometimes the whole dorsum of the mesonotum is gray. Abdomen with broad, white, basal, segmental bands; venter all white. Legs largely black-scaled.

MALE HYPOPYGIUM.—The hypopygium of *Aedes trichurus* Dyar can be separated from all the other species of *Aedes* in Minnesota by the structure of the claspette alone. Stem of claspette long, curved outward, expanded at apex; filament very short, swollen, pointed at apex with a series of concentric ridges.

LARVAE.—The presence of several dorsal hair tufts on the air-tube distinguishes the larvae from the other *Aedes*.

Life Cycle: This species overwinters in the egg stage and the larvae are among the first to appear in the northern swamps in the spring. The few records of larvae were taken between May 19 and June 8, which are rather late dates since adults are common on the wing before that time. The adults emerge ahead of *communis,* being in the very early group of *impiger, intrudens,* and *stimulans,* where they appear together. The latest record of adults is July 17.

Dyar (1923) has given a graphic account of the swarming of this species at Warroad, Minnesota, on May 21, 1922. Several small swarms of males, numbering about 50 each, were observed at dusk to come from a woods and drift out over a meadow high enough from the ground to be out of reach, except in one case where he was able to capture some in a net. The following day at the same place this phenomenon was not observed.

Larval Habitats: The information on larval habitats is decidedly incomplete. The larvae were taken from pools partially shaded in a tamarack swamp and from an open bog where there was a mat of moss. These were associated with *Aedes canadensis* Theobald, *Aedes cinereus* Meigen, *Aedes communis* DeGeer, *Aedes intrudens* Dyar, and *Aedes punctor* Kirby.

Importance: *Aedes trichurus* Dyar feeds readily when encountered in the woods, although it is a less active and voracious species than *communis*. It has not been found in large numbers at any place in

northern Minnesota and would, therefore, be regarded among the species of minor importance.

Distribution: (Fig. 4) Limited to the northern forested region.

Aedes triseriatus Say

1823 *Culex triseriatus* Say. Jour. Acad. Nat. Sci. Phila. 3:12.

Recognition Characters: ADULTS.—This is a small mosquito in which the mesonotum is dark brown in the middle, silvery-white on the sides and anterior margin. Abdomen dark-scaled with lateral, segmental patches of white scales; venter white. The silvery-white scales on the sides of the thorax separate it from the other Minnesota *Aedes*.

MALE HYPOPYGIUM.—The hypopygium is easily recognized by the absence of the apical lobes and the presence of a large tuft of setae about two-thirds of the way out on the inner margins of the side-pieces.

LARVAE.—Antennae smooth with a single, long hair in the middle. Upper head hairs single, lower usually double. A pair of multiple hair tufts in front of and between the lower head hairs. Air-tube two and one-half times as long as wide, stout. Anal gills short, budlike, about as long as the anal segment.

Life Cycle: The winter is passed in the egg stage and the larvae appear about the first week of May in Minnesota. From the contents of a treehole brought into the laboratory on May 2, 1936, large numbers of larvae hatched on May 5. Another treehole, discovered on May 22, contained large numbers of larvae in the second and third instars. Larvae hatching on May 5 in an outdoor insectory emerged as adults on May 24. Whether there is but a single generation each season in Minnesota has not been determined. Adults are to be taken throughout the summer, the latest record being August 23.

Larval Habitats: The larvae have been taken only from treeholes, although it is stated by Howard, Dyar, and Knab (1917) that they may occur in artificial receptacles when these are left in the woods. *Aedes triseriatus* Say is the only species of mosquito known to occur in Minnesota which breeds in treeholes.

Importance: This species feeds when encountered in the woods during the day, but, although the bite is painful, it is not a vicious mosquito. It has been the writer's experience that a slight movement of the body or a change in the air current is sufficient to interrupt feeding. It has never been found in large numbers in any one locality and is of minor importance in the state.

Distribution: (Fig. 8) *Aedes triseriatus* Say is probably confined to the hardwood forest of the state.

Aedes trivittatus Coquillett

1902 *Culex trivittatus* Coquillett, Jour. N. Y. Ent. Soc. 10:193.

Recognition Characters: ADULTS.—Occiput white-scaled, mesonotum brown in the middle with broad, yellowish, sub-dorsal, lateral

stripes, brown on the margin. Abdomen dark brown above, narrow, basal, segmental white bands broadening at the sides; venter whitish-scaled. Legs black.

MALE HYPOPYGIUM.—Apical lobe of side-pieces small, bare; basal lobe represented by a group of a dozen small setae adjacent to a large, strong spine, swollen on its basal part. Claspette with a short, uniform stem, the filament large, curved, swollen in the middle, and with a single, very small retrorse spine.—Dyar (1928).

LARVAE.—Upper and lower head-hairs single, anteantennal tuft multiple. Antennae moderate, slender, a small tuft at the middle. Lateral comb of eighth segment of many scales in a triangular patch. Air-tube two and one-half times as long as wide; the pecten slightly exceeding the middle, followed by a hair tuft. Anal segment ringed by the plate. Anal gills long, tapered, pointed.—Dyar (1928).

Life Cycle: There is little known about the life cycle of this species. Howard, Dyar, and Knab (1917) state that the winter is probably spent in the egg stage and that there are probably several broods during the year, the eggs hatching when conditions are favorable. Adults have been taken in Minnesota from June 12 to August 21, yet the writer has not been fortunate enough to collect the larvae. On July 4, 1932, large numbers of recently emerged adults were encountered along the Rock River near Luverne. These had obviously emerged from the overflow pools on the narrow flood plains, yet no larvae were found at this time.

Larval Habitats: The larvae are said to be more often found in floodwater pools along rivers.

Importance: The adults feed when encountered during the day, both in shade and in the open. The bite of this mosquito is the most painful in the writer's experience of any species in Minnesota. The distribution as well as the abundance is spotted, but to encounter this species in large numbers is an experience not to be forgotten.

Distribution: (Fig. 8) The data at hand suggest that this species is to be found everywhere in the state except in the region of coniferous forests.

Aedes vexans Meigen

1820 *Culex vexans* Meigen, Syst. Beschr. Eur. Zweifl. Ins. 6:241.

Recognition Characters: ADULTS.—This is a medium-sized mosquito easily recognized by the brown mesonotum, broad, white, basal, segmental bands on the abdomen, and narrow, basal, white rings on the tarsi. The wings are dark-scaled and the proboscis is slender, black.

MALE HYPOPYGIUM.—The hypopygium is unique in lacking both the apical and basal lobes of the side-pieces and the filament of the claspette. Clasper gradually expanding to apex, furcate.

LARVAE.—Lower head-hairs double, upper multiple. Lateral abdominal hairs multiple on the first and second segments, double on the third to the fifth, and single on the sixth. Comb scales of eighth segment

about 10 to 12 in number and arranged in an irregular, double row. Air-tube three times as long as wide; pecten extends beyond the middle, last two teeth detached outwardly; tuft located beyond the middle of the air-tube.

Life Cycle: The winter is passed in the egg stage and the larvae appear toward the last of April. There is apparently a single generation each season. Hearle (1926) has shown that all the eggs do not hatch at the same time and that larvae appear periodically after alternate wetting and drying of the eggs during the course of the summer. This characteristic of the eggs offers an explanation for the appearance of larvae at very late dates in the season. Further evidence in favor of a single generation each season is found in the observation of Mail (1934), who demonstrated that eggs of this species require the stimulus of below-freezing temperatures before hatching will take place. On various occasions, the writer has taken larvae in the first instar from pools known to have been dry and recently filled with rain water.

Larvae have been taken in Minnesota periodically from April 28 to July 23. That larvae are to be found at much later dates than this is supported by the appearance of a veritable scourge of *Aedes vexans* Meigen in the region of the Twin Cities during the first week in September, 1935. Adults have been taken as late as October 2; these, presumably, having emerged in September.

Larval Habitats: The larvae of *Aedes vexans* Meigen are more often found in temporary rain pools where there is some decaying vegetation. These are not limited, however, to such habitats as shown by the fact that they have been found in semipermanent and permanent ponds, marshes, woodland pools, cold forest pools, and foul, stagnant puddles. Apparently, they may be found in any type of natural standing water except lakeshores and open bogs. The larvae are commonly found in the same pools with *Aedes cinereus* Meigen and are associated with about equal frequency with *Aedes canadensis* Theobald, *Aedes communis* DeGeer, *Aedes diantaeus* H., D., and K., *Aedes dorsalis* Meigen, *Aedes excrucians* Walker, *Aedes fitchii* Felt and Young, *Aedes flavescens* Müller, *Culex tarsalis* Coquillett, *Theobaldia inornata* Williston, and *Culex territans* Walker.

Importance: *Aedes vexans* Meigen is one of the most widely distributed and abundant mosquitoes in the state. The adults feed in the shade during the day and are especially annoying at dusk. They enter houses freely in search of food and the bites are particularly painful to most people. This mosquito is usually not abundant during May in Minnesota. A wave of emergence often occurs in early June and then successively through the summer, depending upon the amount of precipitation. Thus, it often becomes abundant at a time when the early spring species are disappearing. This species is, by all odds, the most important mosquito in Minnesota outside the limits of the coniferous forest.

Matheson, Burnett, and Brody (1931) demonstrated that this species may prove to be an important agent in the spread of fowl-pox.

Distribution: (Fig. 9) Generally distributed over the entire state, but more common in the hardwood and prairie regions.

Anopheles maculipennis Meigen

1818 *Anopheles maculipennis* Meigen, Syst. Beschr. Zweifl. Ins. 1:11.

Recognition Characters: ADULTS.—The four dark patches on the wing veins and the yellowish-bronzy spot at the apex of each wing are sufficient to identify this species.

MALE HYPOPYGIUM.—For recognition of the hypopygium of this species the reader is referred to the key for identification of the anopheline mosquitoes.

LARVAE.—The characters listed in the key for identification of larvae are the most specific available.

Life Cycle: The winter is passed as adults, only the females hibernating while the males die in the late fall. With the appearance of warm weather in the spring, the females come out of hibernation and deposit eggs. The earliest record of adults being captured in the wild is May 18, at Basswood in Lake County. Since this species is never so abundant as most of the aedine mosquitoes, it is very probable that farther south in the state the adults are active much earlier and have passed unnoticed. The earliest record of larvae being taken is May 30, and they are not common until the latter part of June. Field observations indicate that the larval population is very low in early June and that the peak of abundance is reached in July. Many of the favorite breeding places dry up in late July, and, as a result, the number of larvae diminishes. The latest record of larvae is August 13, although they certainly are present in favorable habitats at a much later date. The number of generations each season in Minnesota has not been determined. Under what conditions hibernation may take place in nature is not only of scientific interest but is of practical importance in the maintenance of the species.

In the fall of 1935, a survey of several caves in the banks of the Minnesota and Mississippi rivers was made for the presence of this species. In four of these caves, *maculipennis* in varying numbers was found. It was the intention of the writer to follow the history of these individuals through the winter. Two of these caves were very small—about eight feet in depth and large enough at the opening for a man to enter. A third cave was in the form of a long, narrow tunnel extending back about 20 feet into a bank of solid sand. The fourth cave was a very extensive one, originally excavated for sand and later used for the growing of mushrooms, but now abandoned. A few *maculipennis* were found in the deeper recesses of this cave and a small group on the walls of an anteroom by the entrance. The relative humidity of all these caves was practically 100 per cent and the walls were wet with moisture. The temperature of the small caves on November 11 was 35° F., while the

temperature of both the deeper caves was 44° F. Again, on December 20, the temperature of the two small caves was above freezing and the temperature of the mushroom cave had not changed, yet, on this date, the temperature outside was below 0° F. The months of January and February, 1936, established a record for low temperatures for Minnesota for a period of 46 years.

When the caves were again visited on March 2, all the mosquitoes in the two small caves were frozen in the ice on the walls. None could be found in the medium-sized cave, while in the large mushroom cave all those on the walls of the small anteroom by the entrance were dead. Those in the deeper recesses could not be located. The significant fact is that these adults selected, in the two cases out of four where they were found, a place for hibernation which did not afford adequate protection from the severe cold.

Larval Habitats: The larvae occur more often in semipermanent and permanent ponds along the shoreline where there are aquatic plants and algae. They have also been taken from temporary rain pools, woodland pools, marshes, open bogs, and the shoreline of streams. The larvae have been found in association with *Anopheles punctipennis* Say, *Culex apicalis* Adams, *Culex tarsalis* Coquillett, *Uranotaenia sapphirina* O. S., and *Anopheles quadrimaculatus* Say.

Importance: *Anopheles maculipennis* Meigen feeds only at dusk and shortly after dark. The bite is annoying but not so severe as that of many of the aedine species. It has a fondness for entering houses and is, therefore, a minor pest in many lake cottages in northern Minnesota. While living in a cottage near Carlton during the summer of 1934, the writer was at a loss to explain the presence of this species indoors in spite of very definite precaution taken to exclude mosquitoes. After several evenings of annoyance, it was learned that the invaders were coming down the chimney of the fireplace. This observation was tested thoroughly by exterminating all mosquitoes in the cabin, by using a spray, and then stretching cheesecloth tightly over the opening of the fireplace. This procedure was repeated on several consecutive evenings and, in each instance, nearly a dozen individuals of this species were trapped behind the cheesecloth. There were several aedine species present out of doors, but none were taken from behind the cloth screening.

As *Anopheles maculipennis* Meigen is a good vector of malaria in many parts of the world, its importance in the spread of this disease in Minnesota always is to be considered.

Distribution: (Fig. 10) This species is confined to the northern half of the state, being more common in the timbered region.

Anopheles punctipennis Say

1823 *Culex punctipennis* Say, Jl. Acad. Nat. Sci. Phila. 3:9.

Recognition Characters: ADULTS.—This species can be separated from all the other anopheline mosquitoes in Minnesota by the presence

of yellowish-white spots on the wings, one of which always involves the costal vein.

MALE HYPOPYGIUM.—The characters listed in the key for identification of the *Anopheles* are sufficient for identification.

LARVAE.—The reader is referred to the key as the larvae of all the anopheline species in Minnesota are very similar and separated with difficulty.

Life Cycle: This species hibernates in the adult stage and the females become active with the appearance of warm weather in the spring. Records of the early activity of overwintering females in Minnesota are not available. Mature larvae have been found on July 14; this, however, is doubtless not the earliest such record to be obtained. Field observations indicate that the larvae are most abundant during late June and July and, naturally, are found less frequently in late summer when many of the breeding places have dried. The latest record of larvae being taken is August 13.

Hibernating females were collected from a small cave near Fort Snelling on January 5, 1935. One of these took a blood meal the following day and was caged over water in the laboratory. Oviposition occurred on January 14, and a part of the eggs hatched on January 18. The unhatched eggs were apparently infertile.

Females were under observation during the winter of 1935-36 in the small cave on the Minnesota River which was described under the discussion of *Anopheles maculipennis* Meigen. When this cave was examined on March 2, 1936, all of the *punctipennis* individuals were found frozen in the ice on the walls. This species, like *maculipennis,* had selected a place for hibernation which did not afford adequate protection.

Larval Habitats: The larvae are more often found in semi-permanent ponds and temporary rain pools. They have been taken in marshy habitats and, in one instance, along the margin of a small stream. The larvae are always found in waters containing a growth of algae and aquatic plants. They have been found in association with *Anopheles maculipennis* Meigen, *Anopheles quadrimaculatus* Say, *Culex apicalis* Adams, *Culex tarsalis* Coquillett, *Uranotaenia sapphirina* O. S., and *Culex territans* Walker.

Importance: The adults feed by preference at twilight, but are also said to attack during the day. This species is of very minor importance in Minnesota.

Distribution: (Fig. 10) *Anopheles punctipennis* Say is more common in the southern half of the state. It is to be found in the northern plains region, but has never been taken within the limits of the coniferous forest.

Anopheles quadrimaculatus Say

1824 *Anopheles quadrimaculatus* Say, Keat. Narr. Exp. St. Peters Riv. 2:356.

Recognition Characters: ADULTS.—This species is to be separated from the other anopheline mosquitoes of the state by the four indistinct

dark spots on the wings and the palpi which are all black, lacking white rings at the joints. There is also the absence of a yellowish patch of scales at the apex of each wing.

MALE HYPOPYGIUM.—The characters listed in the key are the most exact of those available for use in identifying this species.

LARVAE.—The larvae are to be separated from those of *walkeri* by the characters given in the key.

Life Cycle: The life cycle of this species in Minnesota is very incompletely known. The females hibernate as do the other anopheline species. The approximate time the females come out of hibernation in the spring and how early larvae may be found are unknown. The larvae have been taken in late June and July and then only sparingly. A single female was taken in hibernation from a cave by the Mississippi River near St. Paul on November 11, 1935.

Larval Habitats: The larvae have been taken from semipermanent and permanent ponds and temporary rain pools containing algae and other aquatic vegetation. A permanent lily pond in the arboretum on the campus at the University of Minnesota has contained larvae of this species on several occasions. The larvae have been taken in association with *Anopheles punctipennis* Say and *Anopheles maculipennis* Meigen.

Importance: As a pest of man this species is of no importance in Minnesota, but, on the other hand, being a good vector of malaria, its importance in relation to this disease can not be ignored.

Distribution: (Fig. 10) The distribution is incompletely known in the state. Of particular interest, however, is the finding of a single male reared from larvae taken from Jay Cook State Park, Carlton County, since this may represent the very northern limits of its distribution.

Anopheles walkeri Theobald

1901 *Anopheles walkeri* Theobald, Mon. Culicidae 1:199.

Recognition Characters: ADULTS.—The segments of the palpi are white-scaled and the wings show indistinct dark patches similar to *quadrimaculatus*. The wings lack the yellow patch of scales at the apices.

MALE HYPOPYGIUM.—The characters listed in the key for separation of species are those most readily observed.

LARVAE.—The larvae are difficult to separate from *quadrimaculatus*. The characters listed in the key are the most specific.

Life Cycle: *Anopheles walkeri* Theobald spends the winter in the adult stage like the other members of this genus to be found in Minnesota. The adults doubtless come out of hibernation early in May, although the earliest record in this study is May 23. The few larvae that have been found were taken in July and August. The life cycle is incompletely known in Minnesota.

Larval Habitats: The larvae have been found in semipermanent ponds, temporary rain pools, and along the shoreline of a small stream.

They are apparently always associated with algae and other aquatic vegetation. The larvae were taken in association with *Culex apicalis* Adams, *Culex salinarius* Coquillett, and *Culex tarsalis* Coquillett.

Importance: This species will feed in the shade or on a cloudy day as well as at twilight. It is of no importance as a pest of man in this state. However, the recent demonstration by Matheson, Boyd, and Stratman-Thomas (1933), that this mosquito is an efficient vector of malaria, may be of significance in relation to the sporadic occurrence of this disease in Minnesota.

Distribution: (Fig. 10) This species has been taken in both the hardwood and coniferous forest regions. It is probably more or less confined to that part of the state east of the prairies.

Culex apicalis Adams

1903 *Culex apicalis* Adams, Kans. Univ. Sci. Bull. 2:26.

Recognition Characters: ADULTS.—This very small, delicate, culicine species may be identified by the apical, segmental, white bands on the abdomen. Some variation in the width of this band has been observed, yet its presence is always evident.

MALE HYPOPYGIUM.—Apical lobes of side-piece each bearing seven appendages—two heavy, club-shaped rods, two rather long setae, and three short setae. Tenth sternites heavily chitinized, longer than mesosome, and each terminating in a row of stout setae. Mesosome shorter than tenth segment; the distal halves connected by a narrow bridge, and each terminating in a serrated tip. The bridge connecting the two halves of the mesosome will be sufficient in ordinary preparations to identify this species.

LARVAE.—The larvae of this species may be separated from those of the other culicine mosquitoes of Minnesota by the single, long, upper and lower head hairs.

Life Cycle: The winter is passed as hibernating females which become active with the appearance of warm weather in the spring. There are apparently several generations each season as the larvae have been found from May 27 to August 16. It is not known under what conditions the females spend the winter months.

Larval Habitats: These are more often found in marshy localities and around the margins of semipermanent and permanent ponds. They have been found also in temporary rain pools, open bogs, shaded woodland pools, and cold forest pools. The larvae are found in association with *Culex tarsalis* Coquillett, *Culex territans* Walker, *Theobaldia inornata* Williston, *Culex salinarius* Coquillett, *Uranotaenia sapphirina* O. S., *Anopheles punctipennis* Say, *Anopheles maculipennis* Meigen, and *Aedes cinereus* Meigen.

Importance: *Culex apicalis* Adams has never been reported as feeding on man. Efforts by the writer to induce it to feed on his person were entirely unsuccessful. Shannon (1915) has reported capturing

adults that were feeding on the bullfrog *(Rana catesbeiana)* and suggests that the normal hosts of this mosquito are cold-blooded, vertebrate, animals. It is of no known importance in Minnesota.

Distribution: (Fig. 11) This species can doubtless be found in all parts of the state.

Culex pipiens Linnaeus

1758 *Culex pipiens* Linnaeus, Syst. Nat. ed. 10, 602.

Recognition Characters: ADULTS.—A medium-sized, brown mosquito with black legs and basal, segmental, white bands on the abdomen. Mesonotum brown, two narrow, bare lines in front; scales narrow, curved.

MALE HYPOPYGIUM.—Apical lobes well developed, each bearing eight appendages; these are, reading from the base outward—three rods, two setae, a filament, a leaf, and a seta. Mesosome paired, each half with three processes, the median one bladelike and curved outward.

LARVAE.—Upper and lower head hairs multiple. Lateral abdominal hairs multiple on the first and second, and double on the third to sixth segments. Air-tube gradually tapering to apex; pecten of about twelve teeth on proximal fourth of tube; hair tufts usually four beyond the pecten, with the third one slightly dorsal and out of line.

Life Cycle: The winter is passed as hibernating, adult females. These are to be found in the winter months in cellars, basements, and other warm, dark places about human habitation which afford protection from the cold. In the early spring, these females become active and oviposition occurs. Little attention has been given to the seasonal cycle of this species in Minnesota. The larvae have been taken on several occasions from artificial receptacles in the region of the Twin Cities. There are several generations each season.

This species has been observed to hibernate in large numbers in the large mushroom cave on the Mississippi River in St. Paul. It has also been taken in hibernation from the small caves along the Minnesota River and the Mississippi River near St. Paul. The writer visited these caves periodically during the winter of 1935 and 1936. On March 2, 1936, after the prolonged cold period of January and February, all the *pipiens* in the small caves were found frozen in the ice on the walls. The number of *pipiens* in the large mushroom cave was beyond estimation. In many chambers of the cave the individuals were perched on the walls so close together that their feet were in contact and overlapped. There were literally millions of them present. One gained the impression that all the *pipiens* in St. Paul had gone to the cave for hibernation. This large cave was last visited on April 10, when it was found that the *pipiens* were migrating from the deeper recesses to the entrance.

Larval Habitats: The larvae have been taken only from artificial receptacles, although they may infrequently occur in ground pools.

They were taken in association with *Culex territans* Walker and *Culex salinarius* Coquillett.

Importance: This species is often called the northern house mosquito or rain-barrel mosquito and is said to be troublesome in many parts of the United States. It invades houses readily and feeds in the evening. The adults have been taken from time to time in the St. Anthony Park district by University Farm, yet they are never troublesome there. Their abundance, without doubt, varies in different villages and even in different urban communities of the same city.

Kligler, Muckenfuss, and Rivers (1929) have shown that this species can transmit fowl-pox, a rather common disease of poultry found in Minnesota and elsewhere.

Distribution: *Culex pipiens* Linnaeus is undoubtedly found to be present in all parts of the state. No extensive survey has been made to determine its distribution in Minnesota.

Culex salinarius Coquillett

1904 *Culex salinarius* Coquillett, Ent. News 15:73.

Recognition Characters: ADULTS.—The absence of basal white bands on the abdomen will separate this mosquito from the other culicine species in the state.

MALE HYPOPYGIUM.—Apical lobe with six appendages; these are, reading from base outward: three rods with hooked tips, a leaflike appendage, and two setae. Each half of mesosome in three processes, the upper or median one having several sharp, well-spaced teeth beneath it, the lateral process having a tooth arising from the outer angle.

LARVAE.—The very long, straight air-tube, which is seven and one-half to eight times as long as wide, will identify this species. Pecten on basal sixth of tube followed by four small tufts of hair, the subapical one being out of line.

Life Cycle: The life cycle of this species in Minnesota is incompletely known. The females hibernate, as is true with the other species of this genus occurring in the state. The larvae have been taken during June and July.

Larval Habitats: The larvae have been taken from the margin of semipermanent ponds, marshes, and temporary rain pools. They have been found more often in association with *Culex apicalis* Adams. Other species with which they are in association are: *Culex territans* Walker, *Theobaldia inornata* Williston, *Anopheles punctipennis* Say, and *Anopheles walkeri* Theobald.

Importance: This species is stated by Headlee (1921) as having the same habit of frequenting houses as does *pipiens,* and, if near its breeding grounds, it may prove troublesome. It is not a common species in Minnesota and, insofar as known, it is of no importance.

Distribution: (Fig. 11) The distribution records are from rather

widely separated localities, indicating that it may be found over the greater part of the state with the possible exception of the northern swamps.

Culex tarsalis Coquillett

1896 *Culex tarsalis* Coquillett, Can. Ent. 28:43.

Recognition Characters: ADULTS.—This species may be easily separated from all the other culicine mosquitoes by the white ring at the middle of the proboscis.

MALE HYPOPYGIUM.—Apical lobes prominent, bearing three rods, a filament, a small leaf, and a long seta. Mesosome divided, each half with three processes, the outer one fimbriated at tip showing three or four teeth.

LARVAE.—Antennae long, tuft situated beyond the middle, basal part enlarged and spined, apical part smooth. Lateral abdominal hairs of the third to sixth segment triple. Air-tube about four times as long as wide; pecten confined to the basal third; five pairs of tufts beyond the pecten, these becoming smaller toward the apex.

Life Cycle: The adult females overwinter in places that afford protection. Their hibernating quarters in Minnesota have not been observed. Oviposition by these females occurs in the early spring and generation follows generation all summer. The earliest collection of larvae was taken on May 14, and the latest on July 30. They are certainly to be found in pools which have not dried at a much later date. The larvae of this species are in greatest abundance during late June and early July. After this date, many of their favorite breeding grounds disappear.

Larval Habitats: The larvae of *Culex tarsalis* Coquillett are found in a variety of habitats, occurring more often in temporary ground pools, along the margin of semipermanent and permanent ponds, marshes, woodland pools, and foul, stagnant pools. They have been taken sparingly from open bogs and lakeshores. Larvae which thrive in a diversity of habitats are naturally to be found associated with a large number of other species. This species has most commonly been taken with *Theobaldia inornata* Williston, *Culex territans* Walker, *Culex apicalis* Adams, *Anopheles punctipennis* Say, *Anopheles maculipennis* Meigen, *Aedes vexans* Meigen, *Aedes cinereus* Meigen, and *Aedes canadensis* Theobald.

Importance: The writer has never encountered adults of this species in large numbers, yet the ease with which larvae can be found during late June and July in the prairie counties testifies to their abundance. The feeding habits of this species are not well known and there exists a difference of opinion with respect to its importance as a pest of man. Freeborn (1926) found avian blood corpuscles in the stomachs of captured females. This fact and the infrequency with which they were observed to feed on man led him to suggest that it prefers avian blood. On the other hand, Hearle (1926) states that it enters houses

freely in quest of food and that it readily attacks man. The writer has found the bites to be very painful even to one who is not affected by many of the common species. Both engorged and unfed females have been taken in homes, but unfortunately there has been no opportunity for the study of their natural feeding habits where females were abundant. It is very probable, however, that this species causes considerable annoyance to man in certain communities of the prairie region.

Distribution: (Fig. 11) This species can be found in every section of the state. It is more common in the prairie counties.

Culex territans Walker

1856 *Culex territans* Walker, Ins. Saund. Dipt. 1:428.

Recognition Characters: ADULTS.—This medium-sized, brown mosquito is very similar to *Culex pipiens* Linnaeus, but in perfect specimens it can be separated from the latter by the presence of yellowish-white scales among the brown ones of the mesonotum. These are arranged in the following pattern: A pair on the disk, and scattered yellowish scales on the anterior margin and over the base of the wings.

MALE HYPOPYGIUM.—Apical lobes well developed and bearing six appendages—three rods, a leaf, and two long setae. Mesosome heavily chitinized; each side subquadrate and bearing a single, central tooth; the sides uneven.

LARVAE.—Upper and lower head hairs multiple. Lateral abdominal hairs double on the first and second segments, single on the third to sixth. Air-tube four times as long as wide; pecten on the basal third; several scattered hairs; paired tufts subapical.

Life Cycle: The adult females hibernate in the fall and become active again with the appearance of warm weather. Mature larvae have been taken on May 17, and are to be found all during the summer. There are several generations each season and these may overlap considerably, making it possible to find eggs, larvae in all stages of development, and pupae in the same pool. The types of protection selected by hibernating females in Minnesota have not been observed.

Larval Habitats: The larvae are more often found in marshy localities, temporary ground pools, semipermanent and permanent ponds, and woodland pools. Larvae are commonly associated with *Culex apicalis* Adams, *Culex tarsalis* Coquillett, *Theobaldia inornata* Williston, *Aedes cinereus* Meigen, and *Aedes canadensis* Theobald.

Importance: This species feeds on man quite readily and has a fondness for entering houses. It has been taken on several occasions in the Entomology Laboratory on the third floor of the Administration Building, University Farm, St. Paul. This represents a vertical migration of about 50 feet. The bites are not severe, yet this species is annoying in many communities of the state.

Distribution: (Fig. 11) *Culex territans* Walker can doubtless be found in all parts of the state.

Taeniorhynchus perturbans Walker

1856 *Taeniorhynchus perturbans* Walker, Ins. Saund. Dipt. 428.

Recognition Characters: ADULT.—This genus is closely related to the genus *Culex* and is represented in Minnesota by the single species *perturbans*. The key for separation of genera is, for all practical purposes, sufficient for the identification of this species. It is superficially similar to *Culex tarsalis* Coquillett, and the finding of at least one specimen of the latter, which has four well-developed lower mesepimeral bristles instead of one or two, indicates that the two might be confused if only the key characters were relied upon.

Proboscis with broad, white band of scales in middle, the basal half with black and white scales intermixed. Mesonotum with black and yellow scales intermingled, the yellow ones forming longitudinal lines. Tarsi with broad, white bands at the base, especially on the hind legs.

MALE HYPOPYGIUM.—Apical lobes absent. Basal lobe a triangular area; two chitinized margins meeting on the median surface of the side-piece; a stout, blunt spine arising from the apex. Clasper stout, constricted in the middle, apical part terminating in a spine.

LARVAE.—The structure of the air-tube alone will identify the larvae of this species. Air-tube short, twice as long as wide, fitted for piercing plant tissue.

Life Cycle: The larvae in various stages of development spend the winter in lakes and ponds where they may be found attached to the roots and stems of aquatic plants. Adults begin emerging very early in the spring and are to be found until frost. They have been taken in Minnesota from April 7 to August 19. The number of generations each season is not known.

Larval Habitats: The larvae are to be found usually in permanent ponds and lakes as their slow development is not adapted for temporary waters. There is little known about their habitats and development in Minnesota.

Importance: *Taeniorhynchus perturbans* Walker is painful and persistent in its attacks on man. It is said to migrate considerable distances from its breeding grounds and to enter houses freely. This species is not abundant in the localities that have been investigated in Minnesota. It is altogether possible that in certain places its abundance may lead to annoyance, but the writer has not had the experience of encountering it in large numbers.

Distribution: (Fig. 8) This species is apparently uniformly distributed over the timbered region of the state.

Theobaldia inornata Williston

1893 *Culex inornatus* Williston, U. S. Dept. of Agri. Div. Ornith. and Mam., N. Amer. Fauna No. 7, 253.

Recognition Characters: ADULTS.—A large, grayish-brown mosquito; proboscis long, slightly curved downward, brown and white scales

intermingled. Mesonotum brown-scaled with an admixture of golden yellow, the pale scales forming narrow longitudinal lines on the disk. Abdomen with broad, basal bands of whitish scales, the eighth segment all white; venter pale scaled. Wing scales dark brown with white admixed on the costal margin.

The males are uniformly smaller than the females, the integument is lighter in color, and the wing scales are all dark. For a detailed description of the comparative difference between the size and coloration of the males and females, the reader is referred to Howard, Dyar, and Knab (1915).

MALE HYPOPYGIUM.—Apical lobe absent. Basal lobe large, conical, several stout spines at the apex, smaller setae around the sides. Claspettes absent. Mesosome tapering toward apex, open on ventral and dorsal surfaces.

LARVAE.—Upper and lower head hairs multiple, pair of median tufts between lower head hairs. Lateral abdominal hairs multiple on the first and second segments, double on the third to sixth, and single on the seventh.

Life Cycle: This species overwinters as females and these may appear very early in the spring. It is not uncommon to find them on the wing late in April and annoying on evenings when the temperature is still below 50° F. The earliest record of active adults being captured is April 19. They are to be taken throughout the summer and late fall. Larvae have been taken as early as May 2, but they are more abundant during June and July.

Some random observations made on the habits of this species are worthy of mention. Wild females captured in the early spring and given a blood meal will oviposit readily if caged over water. Ten wild females captured during the first week of May, which refused human blood when it was repeatedly offered, died without depositing eggs. These were caged in an open insectory and lived from one to two weeks. It is assumed that these females had overwintered as they were taken from a light trap in which males did not appear before May 15. Two females, captured on May 4, 1936, accepted a blood meal at once and deposited their eggs four days later. Both of these females died very quickly after oviposition, one of them living less than an hour. The egg rafts contained approximately 100 eggs each and hatched in four days' time at the temperature which prevailed in an outdoor insectory. Even with very poor care, adults were obtained from these larvae in two and one-half weeks.

The females of this species are very hardy as compared with the culicine and aedine species of this region. When these emerge together from the same culture and are permitted to die for purposes of securing specimens for identification, the females of *Theobaldia inornata* Williston are observed to outlive the other species.

There is little known about the mating habits of this species. Howard, Dyar, and Knab (1912) state that Dr. Dyar had observed a pair in

copula resting on the underside of a board and that these were united end to end with their heads in opposite directions. During the summer of 1936, adults of this species were being reared from larvae taken in the wild. Upon emergence, mating was observed to take place in small cages and also in pint fruit jars where the larvae were reared. Mating occurred between individuals that were one day of age and very commonly in those from two to three days old. A slight disturbance, resulting in flight, was often sufficient to induce mating. The males usually approached the females while they were active and became united with the male above, then, presently, the two came to rest with their heads in opposite directions. When not disturbed, they remained in copula from fifteen minutes to an hour or more. Mating in small quarters is apparently uncommon among mosquitoes and has been observed to occur only in a few species. Since *Theobaldia inornata* Williston is a hardy species, these observations suggest that it may easily be established in a caged colony for use in various types of experimental work.[3]

Larval Habitats: The larvae are found in a variety of habitats, being more common in marshes, temporary rain pools, woodland pools, and along the margins of ponds. They are more often associated with *Aedes cinereus* Meigen, *Culex tarsalis* Coquillett, *Culex apicalis* Adams, *Aedes canadensis* Theobald, *Culex territans* Walker, *Aedes excrucians* Walker, and *Aedes vexans* Meigen.

Importance: This species feeds during the day in the shade and also at twilight. At times it appears very bloodthirsty and attacks man with avidity. On the other hand, it is known to feed readily on domestic animals and is said to select these in preference to man. The adults migrate a mile or more from their breeding grounds and are often common in urban communities. Its wide distribution and abundance places it among the mosquitoes of major importance in Minnesota.

Distribution: (Fig. 9) *Theobaldia inornata* Williston is more common in the prairie and hardwood forest regions.

Theobaldia morsitans Theobald

1901 *Culex morsitans* Theobald, Mon. Culic. 2:8.

Recognition Characters: ADULTS.—Proboscis long, black. Mesonotum with bronzy-brown scales, two broad submedian bare stripes, and two shorter bare lines each side of antescutellar space; yellowish-white scales around anterior margin, over posterior bare stripes, and at base of wings. The brown scales and yellowish-white ones are often mingled. Wing scales all black.

MALE HYPOPYGIUM.—Apical lobe of side-piece absent; basal lobe well developed, conical with usually five apical spines. Claspettes absent. Lobes of ninth tergite broad and short, each bearing a group of setae.

[3] Since the preparation of this manuscript, the author has been successful in establishing *Theobaldia inornata* Williston is a caged colony in the laboratory. At the present time, October 1937, the species has been carried through five successive generations under these conditions.

LARVAE.—Upper head hairs multiple, lower double. Lateral abdominal hairs of first and second segments multiple, single on the third to sixth. Air-tube long, six and one-half times as long as wide; pecten of seven or eight teeth on the basal fourth; tuft a group of fine multiple hairs between pecten at base.

Life Cycle: The life cycle of this species is incompletely known in Minnesota. Matheson (1929) states that there is but a single generation each year and that the adults live until late in the season. The larvae have been taken from May 10 to July 3. No adults have been captured during the present study.

Larval Habitats: The larvae have been taken from cold forest pools, marshes, and temporary rain pools, these locality records all being in the northern part of the state. This species is more commonly associated with *Aedes canadensis* Theobald, *Aedes punctor* Kirby, and *Aedes cinereus* Meigen.

Importance: This species will not feed on man, according to Matheson (1929). The few adults obtained in this study came from larvae reared en masse and were killed before their identity was recognized. It is apparently of no importance in Minnesota.

Distribution: (Fig. 9) Coniferous forest of the northern part of the state.

Theobaldia impatiens Walker

This species probably occurs in northern Minnesota, but it was not taken in the course of this study.

Uranotaenia sapphirina Osten Sacken

1868 *Aedes sapphirinus* Osten Sacken, Trans. Amer. Ent. Soc. 2:47.

Recognition Characters: ADULTS.—This small, delicate mosquito may be recognized by the presence of sapphire-colored scales on the thorax and wings. Mesonotum with bronzy-brown scales, a narrow median line of metallic blue scales extending from anterior margin to scutellum, a lateral row of blue scales extending forward from roots of wings to middle of mesonotum. Wing scales brown, basal part of first and fifth veins with blue scales.

MALE HYPOPYGIUM.—Side-piece very short, slightly longer than broad. Claspers short, distal part expanded and terminating in a curved point. Apical lobe absent. Basal lobe short, terminating in two spines. Mesosomal plate divided, each half terminating in two, stout hooks and several small teeth.

LARVAE.—Head much longer than wide. Upper and lower head hairs single. Lateral abdominal hairs triple on first two segments, inconspicuous on the other segments. Lateral comb of eighth segment a row of approximately eight teeth on the posterior margin of a flat, chitinized plate. Anal segment ringed by the dorsal plate. Posterior margin of dorsal plate fringed with a row of fine spines. Air-tube

slender, straight, three times as long as wide; hair tuft about middle of tube; pecten reaching to tuft. The larvae may be recognized in the field by their habit of resting parallel to the surface of the water in the attitude of an anopheline larva.

Life Cycle: The life cycle of this species is incompletely known in its northern range. Hinman (1935) presents data which indicate that in the southern states it may spend the winter either as hibernating females or in the larval stage. Females have not been taken in hibernation in Minnesota and the larvae were found only in July and August. The winter is, without doubt, passed in the adult stage in this latitude.

Larval Habitats: The larvae are to be found in permanent ponds, marshes, temporary rain pools, and, in one instance, were taken from a bog with a sphagnum mat. They were found associated with *Anopheles maculipennis* Meigen, *Anopheles punctipennis* Say, *Culex apicalis* Adams, *Culex tarsalis* Coquillett, and *Culex territans* Walker.

Importance: *Uranotaenia sapphirina* O. S. is of no economic importance in Minnesota. The species is not common and rarely feeds on man.

Distribution: This species can probably be found in all the timbered regions of the state. The finding of larvae at Warba and Swan River in the southern part of Itasca County on August 16, 1933, may mark the northern limit in the range of this species.

Uranotaenia sapphirina O. S. is more common in the southern states. Its northern range in the central United States is incompletely known. Chandler (1920) lists it among the mosquitoes found at Murphysboro and Carbondale, Illinois, while Dyar (1922) gives a record from Toledo, Ohio, and Hinman (1935) reports finding larvae at Dexter, Michigan.

Wyeomyia smithii Coquillett

1901 *Aedes smithii* Coquillett, Can. Ent. 33:260.

Recognition Characters: ADULTS.—This very small, dark mosquito is seldom seen except when reared from larvae. The tuft of setae on the postnotum separates it from all the other species found in the state.

MALE HYPOPYGIUM.—Side-piece long and slender; apical lobes absent. Basal lobe divided into an inner and outer part, the outer lobe represented by three stout spines, the inner one covered with setae. Claspers with distal half enlarged, distorted, and terminating in a spiny knob.

LARVAE.—The larvae are found only in the leaves of the pitcher plant. The absence of a ventral brush on the anal segment separates it from all other Minnesota species.

Life Cycle: The larvae are to be found in various stages of development at all seasons of the year in the leaves of their host plant, *Sarracenia purpurea* L. The adults die in the fall and reappear again in the spring. There are several generations each season.

During the month of August, 1933, the writer made some limited tests on the resistance to freezing of larvae and pupae of this species when subjected to low temperatures in their natural medium—the liquid accumulating at the base of a pitcher-plant leaf. The results in brief are as follows:

Experiment 1. Newly hatched larvae, mature larvae, and pupae were suspended in about 25 cc. of their natural medium and slowly cooled as follows:

+15° C. — 1 hour
+10° C. — 1 hour
+ 7° C. — 5½ hours
−14° C. — 3½ hours

The liquid at −14° C. solidified, expanded, and broke the glass vial. When slowly warmed to room temperature, all the larvae and pupae were dead.

Experiment 2. Experiment 1 was duplicated, except that the test animals remained at +7° C. for 12 hours and at −14° C. for only 2 hours. The medium did not completely freeze solid, yet the animals were surrounded by ice. When slowly warmed, the larvae resumed activity and developed normally. Out of 10 pupae in this test, only one resumed activity and transformed.

Experiment 3. Larvae in various stages of development were placed in a wax-paper container that permitted expansion and cooled as in Experiment 1. These were maintained at +7° C. for 12 hours and kept at −14° C. for 4 hours. When slowly warmed, all were dead.

These tests indicate that, although larvae can withstand freezing, they are destroyed by temperatures near −14° C. The data suggest also that pupae are more susceptible to low temperatures than are larvae. During the winter months the mortality is probably low among these developmental stages as a blanket of snow would offer protection from the very low air temperatures which often prevail.

Larval Habitats: The larvae of this species are found only in the leaves of the pitcher plant, *Sarracenia purpurea* L.

Importance: This species has never been known to feed on man. The writer has made repeated efforts to induce it to feed on his person, but without success. Insofar as known, it is of no economic importance in Minnesota.

Distribution: (Fig. 8) This species is probably to be found wherever its host plant occurs. Little attention has been given to the distribution of this mosquito in Minnesota.

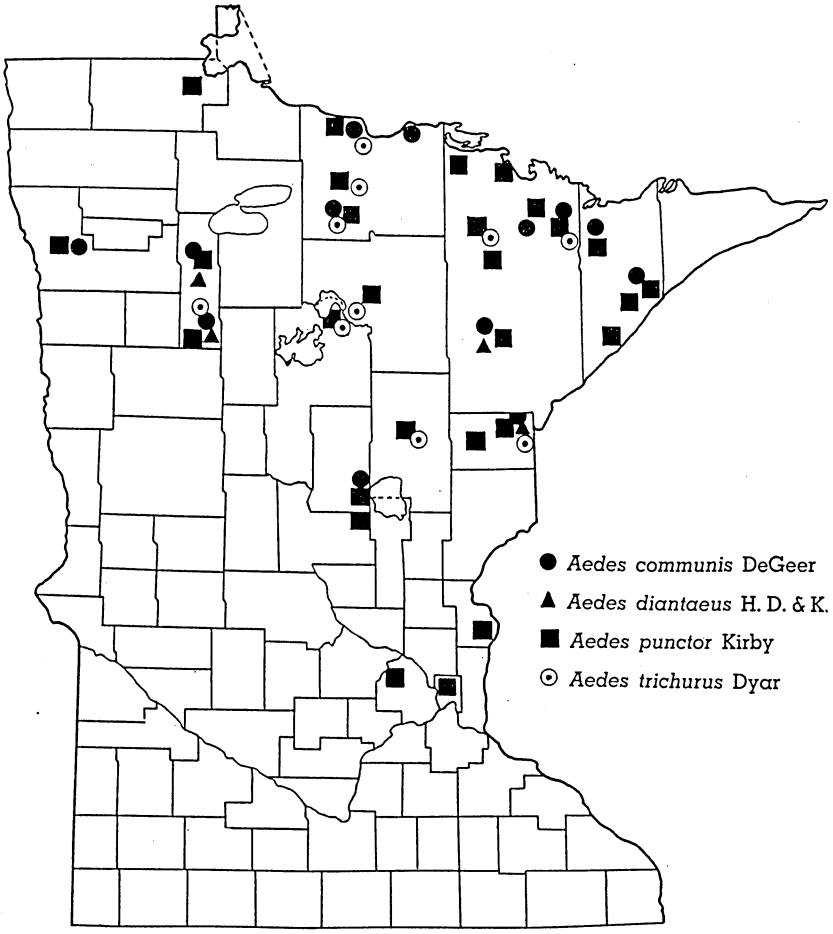

Fig. 4. The Known Distribution in Minnesota of *Aedes communis* DeGeer, *Aedes diantaeus* H. D. & K., *Aedes punctor* Kirby, and *Aedes trichurus* Dyar

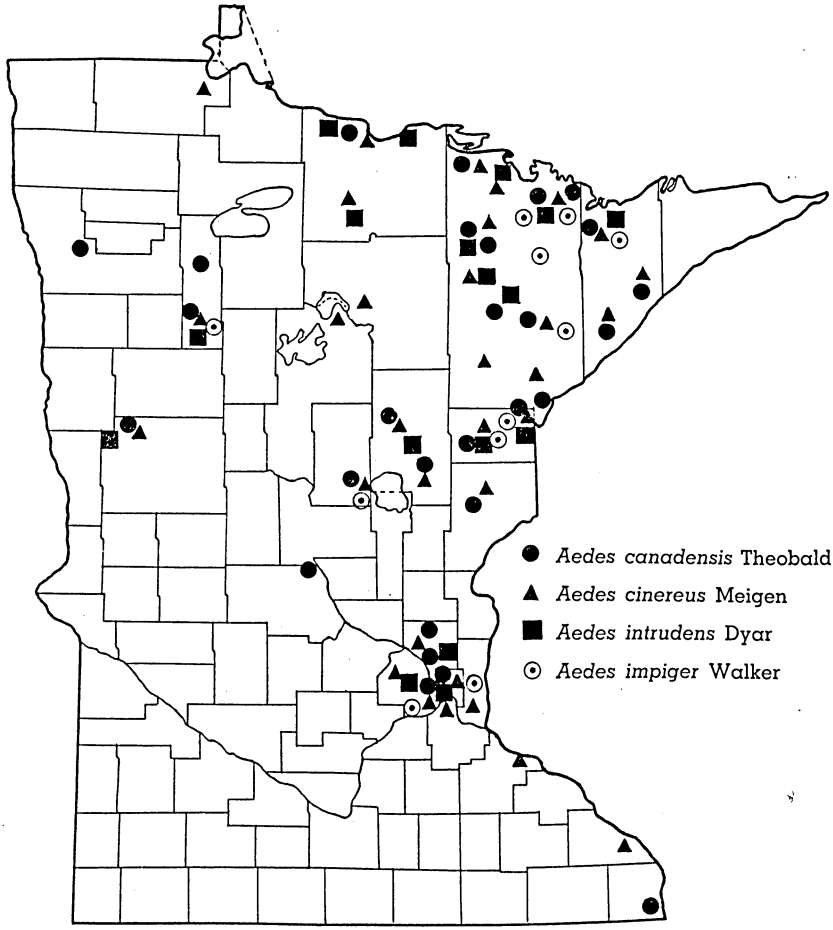

Fig. 5. The Known Distribution in Minnesota of *Aedes canadensis* Theobald, *Aedes cinereus* Meigen, *Aedes intrudens* Dyar, and *Aedes impiger* Walker

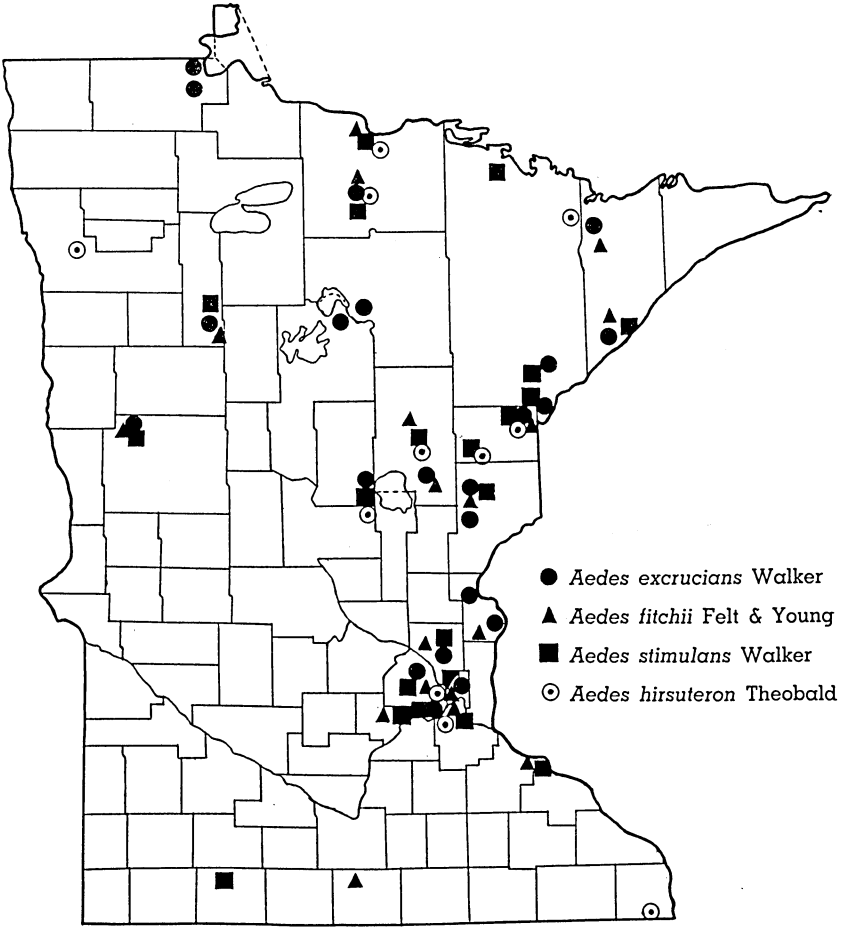

Fig. 6. The Known Distribution in Minnesota of *Aedes excrucians* Walker, *Aedes fitchii* Felt & Young, *Aedes stimulans* Walker, and *Aedes hirsuteron* Theobald

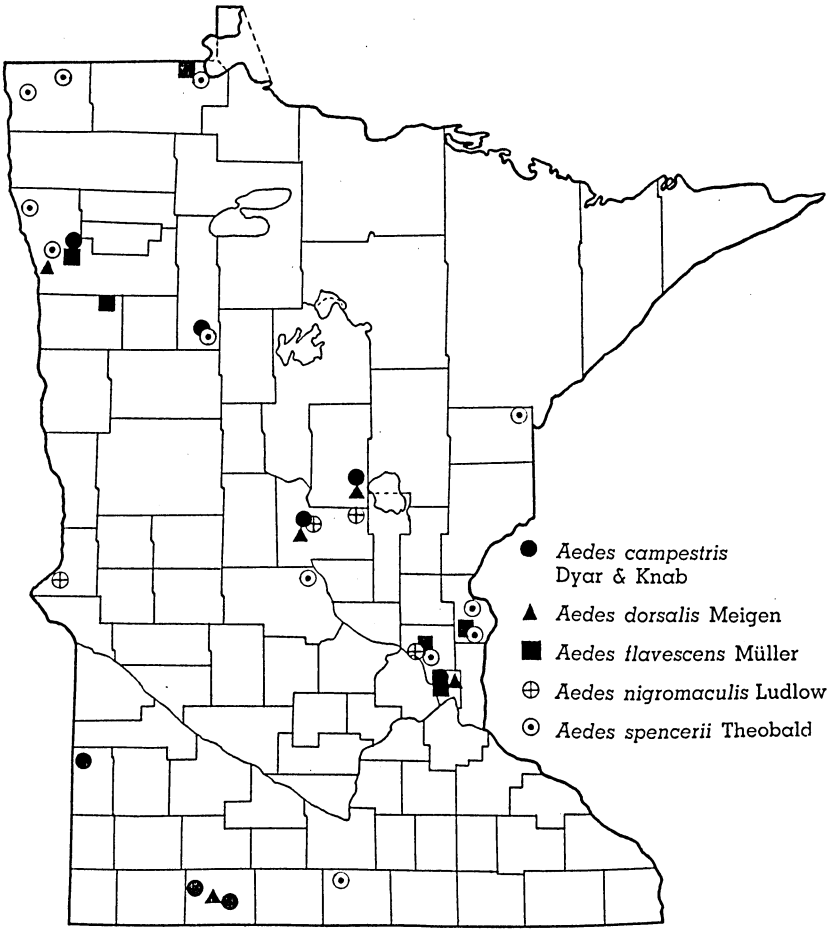

Fig. 7. The Known Distribution in Minnesota of *Aedes campestris* Dyar & Knab, *Aedes dorsalis* Meigen, *Aedes flavescens* Müller, *Aedes nigromaculis* Ludlow, and *Aedes spencerii* Theobald

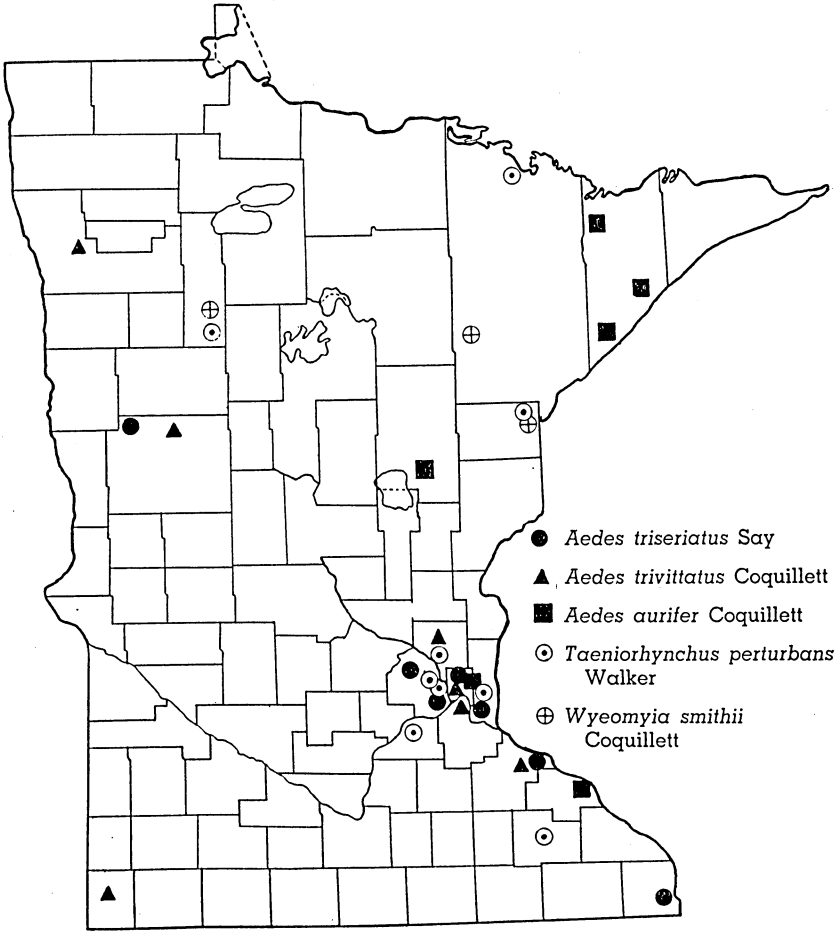

Fig. 8. The Known Distribution in Minnesota of *Aedes triseriatus* Say, *Aedes trivittatus* Coquillett, *Aedes aurifer* Coquillett, *Taeniorhynchus perturbans* Walker, and *Wyeomyia smithii* Coquillett

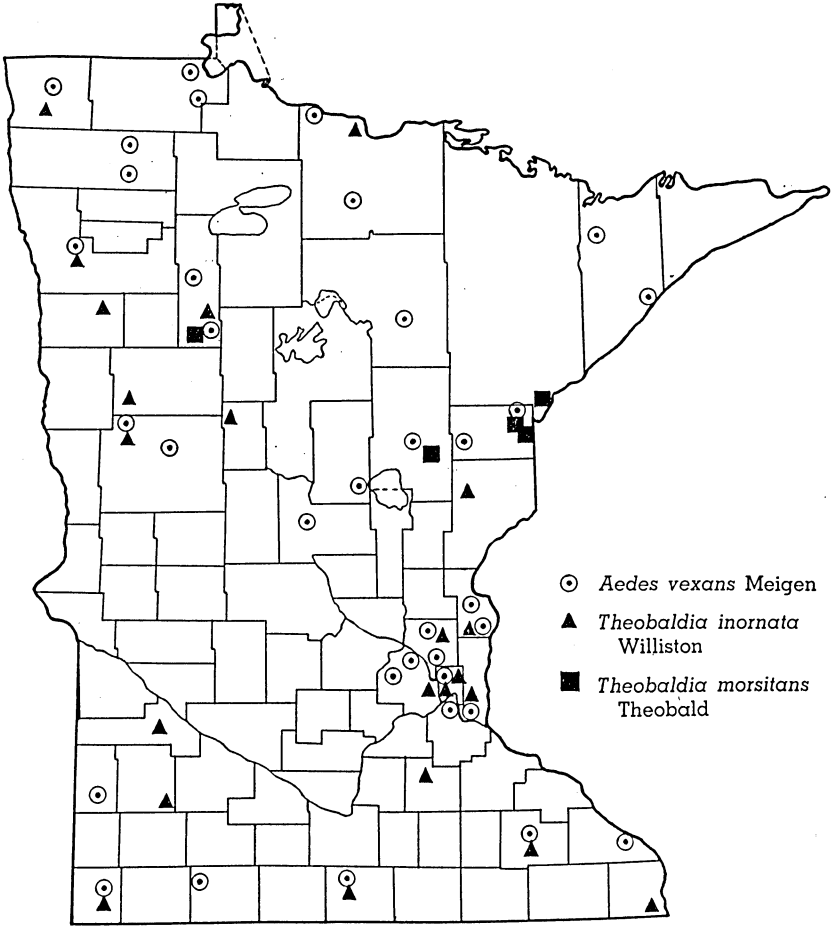

Fig. 9. The Known Distribution in Minnesota of *Aedes vexans* Meigen, *Theobaldia inornata* Williston, and *Theobaldia morsitans* Theobald

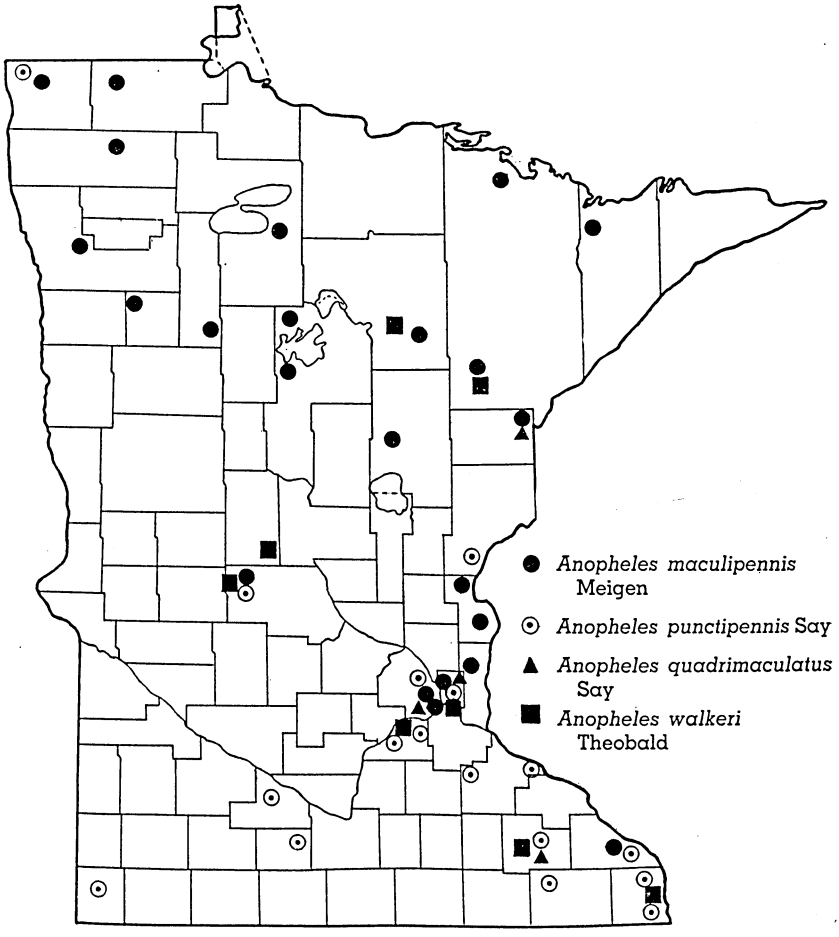

Fig. 10. The Known Distribution in Minnesota of *Anopheles maculipennis* Meigen, *Anopheles punctipennis* Say, *Anopheles quadrimaculatus* Say, and *Anopheles walkeri* Theobald

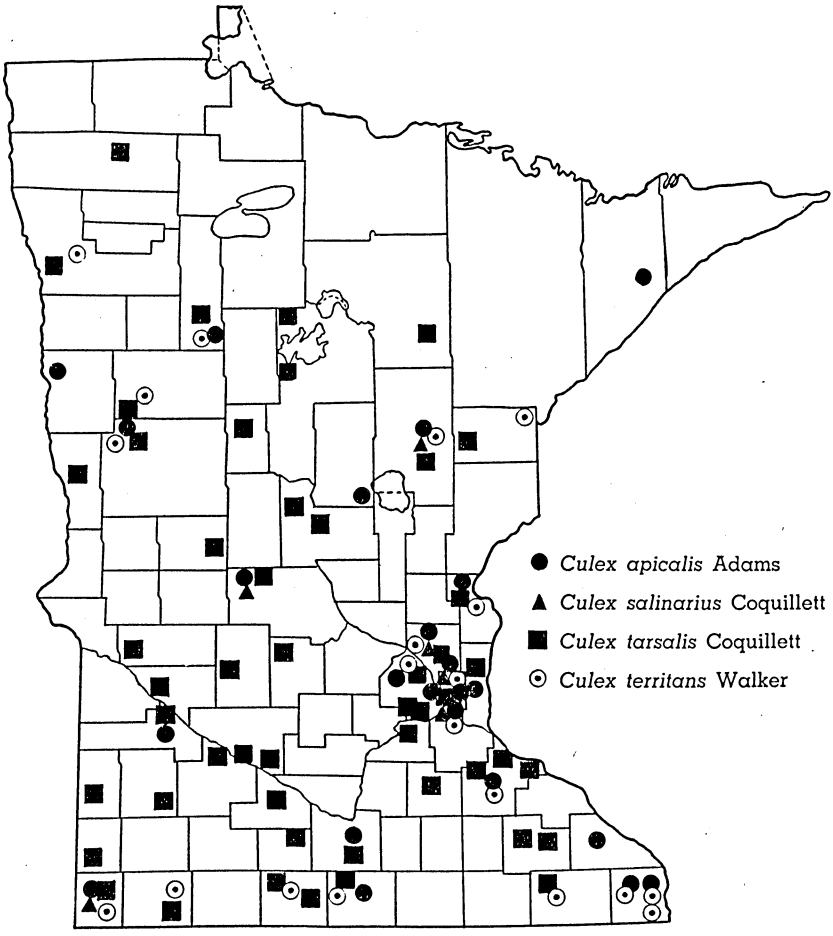

Fig. 11. The Known Distribution in Minnesota of *Culex apicalis* Adams, *Culex salinarius* Coquillett, *Culex tarsalis* Coquillett, and *Culex territans* Walker

IV. SUMMARY

Mosquitoes, although less abundant than in the pioneer period, are still a serious pest of people seeking outdoor recreation in Minnesota. Their greatest abundance today is in the swamps of the coniferous forest.

There are known, at the present time, 7 genera and 37 species of mosquitoes from the state.

Aedes atropalpus Coquillett, a species breeding in potholes is recorded for the first time in Minnesota. This species heretofore was not known to occur in the north central United States.

Uranotaenia sapphirina O. S. is recorded for the first time in the state. The Minnesota records extend the range of this mosquito considerably to the north and west of all previous information.

Four species of *Anopheles* are present. Of these, *Anopheles maculipennis* Meigen and *Anopheles punctipennis* Say are the most common. Malaria can be propagated during the summer months. Its introduction through the presence of "carriers" among the tourists who annually visit the state for recreational purposes is possible though conditions are not favorable for its maintenance.

Keys for identification of adults, male hypopygia, and larvae are presented. With each species is given a brief list of recognition characters. Biological data on individual species are given.

Larval habitats are classified into 13 different categories. Some species of mosquitoes are highly specialized in their breeding habits while others are less restricted. A list of the habitats with the number of species breeding in them is as follows: Pitcher plants, 1; potholes, 1; treeholes, 2; artificial receptacles, 3; streams, 4; lakeshores, 4; foul stagnant pools, 5; bogs, 18; coniferous forest pools, 15; woodland pools, 17; temporary pools, 26; marshes, 20, and ponds, 18. Analysis of these data shows the presence of a rather definite association in the pools of the coniferous forest; some species are typical of treeholes, potholes, pitcher plants, and artificial receptacles; there is little evidence of restricted associations in the other habitats, the more common species occurring there representing species which are widely distributed.

A table giving the number of times various species were taken together in the larval stage is presented. The wide range of these associations among species further emphasizes the variety of conditions under which larvae may be found.

Distribution maps for the common species indicate that in some way their presence is determined by the major vegetational areas or the factors related to their occurrence.

Anopheles maculipennis Meigen, *Anopheles punctipennis* Say, and *Culex pipiens* Linnaeus were observed hibernating in caves near St. Paul. In two out of four caves under observation, these species failed to survive the winter months.

Theobaldia inornata Williston was observed to mate readily in captivity when confined in small cages and also in pint fruit jars.

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